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EDITED BY J. McKEEN CATTELL

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J. McKEEN CATTELL, Editor
WARE CATTELL, Associate Editor

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THE SCIENTIFIC MONTHLY

NOVEMBER, 1937

THE PROGRESS OF PHYSICS[1]

By the late LORD RAYLEIGH

PROFESSOR OF EXPERIMENTAL PHYSICS IN THE UNIVERSITY OF CAMBRIDGE

It is no ordinary meeting of the British Association which I have now the honor of addressing. For more than fifty years the Association has held its autumn gathering in various towns of the United Kingdom, and within those limits there is, I suppose, no place of importance which we have not visited. And now, not satisfied with past successes, we are seeking new worlds to conquer. When it was first proposed to visit Canada, there were some who viewed the project with hesitation. For my own part, I never quite understood the grounds of their apprehension. Perhaps they feared the thin end of the wedge. When once the principle was admitted, there was no knowing to what it might lead. So rapid is the development of the British Empire, that the time might come when a visit to such out-of-the-way places as London or Manchester could no longer be claimed as a right, but only asked for as a concession to the susceptibilities of the English. But seriously, whatever objections may have at first been felt soon were outweighed by the consideration of the magnificent opportunities which your hospitality affords of extending the sphere of our influence and of becoming acquainted with a part of the Queen's dominion which, associated with splendid memories of the past, is advancing daily by leaps and bounds to a position of importance such as not long ago was scarcely dreamed of. For myself, I am not a stranger to your shores. I remember well the impression made upon me, seventeen years ago, by the wild rapids of the St. Lawrence, and the gloomy grandeur of the Saguenay. If anything impressed me more, it was the kindness with which I was received by yourselves, and which I doubt not will be again extended not merely to myself but to all the English members of the Association. I am confident that those who have made up their minds to cross the ocean will not repent their decision, and that, apart altogether from scientific interests, great advantage may be expected from this visit. We Englishmen ought to know more than we do of matters relating to the Colonies, and anything which tends to bring the various parts of the Empire into closer contact can hardly be over-valued. It is pleasant to think that this Association is the means of furthering an object which should be dear to the hearts of all of us; and I venture to say that a large proportion of the visitors to this country will be astonished by what they see, and will carry home an impression which time will not readily efface.

To be connected with this meeting is to me a great honor, but also a great

[1] Presidential address before the meeting of the British Association for the Advancement of Science, Montreal, 1884.

responsibility. In one respect, especially, I feel that the Association might have done well to choose another President. My own tastes have led me to study mathematics and physics rather than geology and biology, to which naturally more attention turns in a new country, presenting as it does a fresh field for investigation. A chronicle of achievements in these departments by workers from among yourselves would have been suitable to the occasion, but could not come from me. If you would have preferred a different subject for this address, I hope at least that you will not hold me entirely responsible.

At annual gatherings like ours the pleasure with which friends meet friends again is sadly marred by the absence of those who can never more take their part in our proceedings. Last year my predecessor in this office had to lament the untimely loss of Spottiswoode and Henry Smith, dear friends of many of us, and prominent members of our Association. And now, again, a well-known form is missing. For many years Sir W. Siemens has been a regular attendant at our meetings, and to few indeed have they been more indebted for success. Whatever the occasion, in his Presidential Address of two years ago, or in communications to the Physical and Mechanical Sections, he had always new and interesting ideas, put forward in language which a child could understand, so great a master was he of the art of lucid statement in his adopted tongue. Practice with Science was his motto. Deeply engaged in industry, and conversant all his life with engineering operations, his opinion was never that of a mere theorist. On the other hand, he abhorred rule of thumb, striving always to master the scientific principles which underlie rational design and invention.

It is not necessary that I should review in detail the work of Siemens. The part which he took, during recent years, in the development of the dynamo machine must be known to many of you. We owe to him the practical adoption of the method, first suggested by Wheatstone, of throwing into a shunt the coils of the field-magnets, by which a greatly improved steadiness of action is obtained. The same characteristics are observable throughout—a definite object in view and a well-directed perseverance in overcoming the difficulties by which the path is usually obstructed.

These are indeed the conditions of successful invention. The world knows little of such things, and regards the new machine or the new method as the immediate outcome of a happy idea. Probably, if the truth were known, we should see that, in nine cases out of ten, success depends as much upon good judgment and perseverance as upon fertility of imagination. The labors of our great inventors are not unappreciated, but I doubt whether we adequately realize the enormous obligations under which we lie. It is no exaggeration to say that the life of such a man as Siemens is spent in the public service; the advantages which he reaps for himself being as nothing in comparison with those which he confers upon the community at large.

As an example of this it will be sufficient to mention one of the most valuable achievements of his active life—his introduction, in conjunction with his brother, of the regenerative gas furnace, by which an immense economy of fuel (estimated at millions of tons annually) has been effected in the manufacture of steel and glass. The nature of this economy is easily explained. Whatever may be the work to be done by the burning of fuel, a certain *temperature* is necessary. For example, no amount of heat in the form of boiling water would be of any avail for the fusion of steel. When the products of combustion are cooled down to the point in question, the heat which they still contain is useless as regards the pur-

pose in view. The importance of this consideration depends entirely upon the working temperature. If the object be the evaporation of water or the warming of a house, almost all the heat may be extracted from the fuel without special arrangements. But it is otherwise when the temperature required is not much below that of combustion itself, for then the escaping gases carry away with them the larger part of the whole heat developed. It was to meet this difficulty that the regenerative furnace was devised. The products of combustion, before dismissal into the chimney, are caused to pass through piles of loosely stacked fire-brick, to which they give up their heat. After a time the fire-brick, upon which the gases first impinge, becomes nearly as hot as the furnace itself. By suitable valves the burnt gases are then diverted through another stack of brickwork, which they heat up in like manner, while the heat stored up in the first stack is utilized to warm the unburnt gas and air on their way to the furnace. In this way almost all the heat developed at a high temperature during the combustion is made available for the work in hand.

As it is now several years since your presidential chair has been occupied by a professed physicist, it may naturally be expected that I should attempt some record of recent progress in that branch of science, if indeed such a term be applicable. For it is one of the difficulties of the task that subjects as distinct as mechanics, electricity, heat, optics, and acoustics, to say nothing of astronomy and meteorology, are included under physics. Any one of these may well occupy the life-long attention of a man of science, and to be thoroughly conversant with all of them is more than can be expected of any one individual, and is probably incompatible with the devotion of much time and energy to the actual advancement of knowledge. Not that I would complain of the association sanctioned by common parlance. A sound knowledge of at least the principles of general physics is necessary to the cultivation of any department. The predominance of the sense of sight as the medium of communication with the outer world, brings with it dependence upon the science of optics; and there is hardly a branch of science in which the effects of *temperature* have not (often without much success) to be reckoned with. Besides the neglected borderland between two branches of knowledge is often that which best repays cultivation, or, to use a metaphor of Maxwell's, the greatest benefits may be derived from a cross-fertilization of the sciences. The wealth of material is an evil only from the point of view of one of whom too much may be expected. Another difficulty incident to the task, which must be faced, but can not be overcome, is that of estimating rightly the value, and even the correctness, of recent work. It is not always that which seems at first the most important that proves in the end to be so. The history of science teems with examples of discoveries which attracted little notice at the time, but afterwards have taken root downwards and borne much fruit upwards.

One of the most striking advances of recent years is in the production and application of electricity upon a large scale—a subject to which I have already had occasion to allude in connection with the work of Sir W. Siemens. The dynamo machine is indeed founded upon discoveries of Faraday now more than half a century old; but it has required the protracted labors of many inventors to bring it to its present high degree of efficiency. Looking back at the matter, it seems strange that progress should have been so slow. I do not refer to details of design, the elaboration of which must always, I suppose, require

the experience of actual work to indicate what parts are structurally weaker than they should be, or are exposed to undue wear and tear. But with regard to the main features of the problem it would almost seem as if the difficulty lay in want of faith. Long ago it was recognized that electricity derived from chemical action is (on a large scale) too expensive a source of mechanical power, notwithstanding the fact that (as proved by Joule in 1846) the conversion of electrical into mechanical work can be effected with great economy. From this it is an evident consequence that electricity may advantageously be obtained from mechanical power; and one can not help thinking that if the fact had been borne steadily in mind, the development of the dynamo might have been much more rapid. But discoveries and inventions are apt to appear obvious when regarded from the standpoint of accomplished fact; and I draw attention to the matter only to point the moral that we do well to push the attack persistently when we can be sure beforehand that the obstacles to be overcome are only difficulties of contrivance, and that we are not vainly fighting unawares against a law of Nature.

The present development of electricity on a large scale depends, however, almost as much upon the incandescent lamp as upon the dynamo. The success of these lamps demands a very perfect vacuum—not more than about one millionth of the normal quantity of air should remain—and it is interesting to recall that, twenty years ago, such vacua were rare even in the laboratory of the physicist. It is pretty safe to say that these wonderful results would never have been accomplished had practical applications alone been in view. The way was prepared by an army of scientific men whose main object was the advancement of knowledge, and who could scarcely have imagined that the processes which they elaborated would soon be in use on a commercial scale and intrusted to the hands of ordinary workmen.

When I speak in hopeful language of practical electricity, I do not forget the disappointment within the last year or two of many over-sanguine expectations. The enthusiasm of the inventor and promoter are necessary to progress, and it seems to be almost a law of nature that it should overpass the bounds marked out by reason and experience. What is most to be regretted is the advantage taken by speculators of the often uninstructed interest felt by the public in novel schemes by which its imagination is fired. But looking forward to the future of electric lighting, we have good ground for encouragement. Already the lighting of large passenger-ships is an assured success, and one which will be highly appreciated by those travelers who have experienced the tedium of long winter evenings unrelieved by adequate illumination. Here, no doubt, the conditions are in many respects especially favorable. As regards space, life on board ship is highly concentrated; while unity of management and the presence on the spot of skilled engineers obviate some of the difficulties that are met with under other circumstances. At present we have no experience of a house-to-house system of illumination on a great scale and in competition with cheap gas; but preparations are already far advanced for trial on an adequate scale in London. In large institutions, such as theaters and factories, we all know that electricity is in successful and daily extending operation.

When the necessary power can be obtained from the fall of water, instead of from the combustion of coal, the conditions of the problem are far more favorable. Possibly the severity of your winters may prove an obstacle, but it is impossible to regard your splendid river without the thought arising that the day may come when the vast powers now run-

ning to waste shall be bent into your service. Such a project demands of course the most careful consideration, but it is one worthy of an intelligent and enterprising community.

The requirements of practice react in the most healthy manner upon scientific electricity. Just as in former days the science received a stimulus from the application to telegraphy, under which everything relating to measurement on a small scale acquired an importance and development for which we might otherwise have had long to wait, so now the requirements of electric lighting are giving rise to a new development of the art of measurement upon a large scale, which can not fail to prove of scientific as well as practical importance. Mere change of scale may not at first appear a very important matter, but it is surprising how much modification it entails in the instruments, and in the processes of measurement. For instance, the resistance coils on which the electrician relies in dealing with currents whose maximum is a fraction of an ampere fail altogether when it becomes a question of hundreds, not to say thousands, of amperes.

The powerful currents, which are now at command, constitute almost a new weapon in the hands of the physicist. Effects which in old days were rare and difficult of observation may now be produced at will on the most conspicuous scale. Consider for a moment Faraday's great discovery of the "Magnetization of Light," which Tyndall likens to the Weisshorn among mountains, as high, beautiful, and alone. This judgment (in which I fully concur) relates to the scientific aspect of the discovery, for to the eye of sense nothing could have been more insignificant. It is even possible that it might have eluded altogether the penetration of Faraday, had he not been provided with a special quality of very heavy glass. At the present day these effects may be produced upon a scale that would have delighted their discoverer, a rotation of the plane of polarization through 180° being perfectly feasible. With the aid of modern appliances, Kundt and Röntgen in Germany, and H. Becquerel in France, have detected the rotation in gases and vapors, where, on account of its extreme smallness, it had previously escaped notice.

Again, the question of the magnetic saturation of iron has now an importance entirely beyond what it possessed at the time of Joule's early observations. Then it required special arrangements purposely contrived to bring it into prominence. Now in every dynamo machine, the iron of the field-magnets approaches a state of saturation, and the very elements of an explanation of the action require us to take the fact into account. It is indeed probable that a better knowledge of this subject might lead to improvements in the design of these machines.

Notwithstanding the important work of Rowland and Stoletow, the whole theory of the behavior of soft iron under varying magnetic conditions is still somewhat obscure. Much may be hoped from the induction balance of Hughes, by which the marvelous powers of the telephone are applied to the discrimination of the properties of metals, as regards magnetism and electric conductivity.

The introduction of powerful alternate-current in machines by Siemens, Gordon, Ferranti, and others, is likely also to have a salutary effect in educating those so-called practical electricians whose ideas do not easily rise above ohms and volts. It has long been known that when the changes are sufficiently rapid, the phenomena are governed much more by induction, or electric inertia, than by mere resistance. On this principle much may be explained that would otherwise seem paradoxical. To take a comparatively simple case, conceive an electro-magnet wound with two contiguous

wires, upon which acts a given rapidly periodic electromotive force. If one wire only be used, a certain amount of heat is developed in the circuit. Suppose now that the second wire is brought into operation in parallel—a proceeding equivalent to doubling the section of the original wire. An electrician accustomed only to constant currents would be sure to think that the heating effect would be doubled by the change, as much heat being developed in each wire separately as was at first in the single wire. But such a conclusion would be entirely erroneous. The total current, being governed practically by the self-induction of the circuit, would not be augmented by the accession of the second wire, and the total heating effect, so far from being doubled, would, in virtue of the superior conductivity, be halved.

During the last few years much interest has been felt in the reduction to an absolute standard of measurements of electromotive force, current, resistance, &c., and to this end many laborious investigations have been undertaken. The subject is one that has engaged a good deal of my own attention, and I should naturally have felt inclined to dilate upon it, but that I feel it to be too abstruse and special to be dealt with in detail upon an occasion like the present. As regards resistance, I will merely remind you that the recent determinations have shown a so greatly improved agreement that the Conference of Electricians assembled at Paris in May have felt themselves justified in defining the ohm for practical use as the resistance of a column of mercury of 0° C., one square millimeter in section, and 106 cm in length—a definition differing by a little more than 1 per cent. from that arrived at twenty years ago by a committee of this Association.

A standard of resistance once determined upon can be embodied in a "resistance coil," and copied without much trouble, and with great accuracy. But in order to complete the electrical system, a second standard of some kind is necessary, and this is not so easily embodied in a permanent form. It might conveniently consist of a standard galvanic cell, capable of being prepared in a definite manner, whose electromotive force is once for all determined. Unfortunately, most of the batteries in ordinary use are for one reason or another unsuitable for this purpose, but the cell introduced by Mr. Latimer Clark, in which the metals are zinc in contact with saturated zinc sulphate and pure mercury in contact with mercurous sulphate, appears to give satisfactory results. According to my measurements, the electromotive force of this cell is 1.435 theoretical volts.

We may also conveniently express the second absolute electrical measurement necessary to the completion of the system by taking advantage of Faraday's law that the quantity of metal decomposed in an electrolytic cell is proportional to the whole quantity of electricity that passes. The best metal for the purpose is silver, deposited from a solution of the nitrate or of the chlorate. The results recently obtained by Prof. Kohlrausch and by myself are in very good agreement, and the conclusion that one ampere flowing for one hour decomposes 4.025 grains of silver, can hardly be in error by more than a thousandth part. This number being known, the silver voltameter gives a ready and very accurate method of measuring currents of intensity varying from one tenth of an ampere to four or five amperes.

The beautiful and mysterious phenomena attending the discharge of electricity in nearly vacuous spaces have been investigated and in some degree explained by De La Rue, Crookes, Schuster, Moulton, and the lamented Spottiswoode, as well as by various able foreign experimenters. In a recent research Crookes has sought the origin of

a bright citron-colored band in the phosphorescent spectrum of certain earths, and after encountering difficulties and anomalies of a most bewildering kind, has succeeded in proving that it is due to yttrium, an element much more widely distributed than had been supposed. A conclusion like this is stated in a few words, but those only who have undergone similar experience are likely to appreciate the skill and perseverance of which it is the final reward.

A remarkable observation by Hall of Baltimore, from which it appeared that the flow of electricity in a conducting sheet was disturbed by magnetic force, has been the subject of much discussion. Mr. Shelford Bidwell has brought forward experiments tending to prove that the effect is of a secondary character, due in the first instance to the mechanical force operating upon the conductor of an electric current when situated in a powerful magnetic field. Mr. Bidwell's view agrees in the main with Mr. Hall's division of the metals into two groups according to the direction of the effect.

Without doubt the most important achievement of the older generation of scientific men has been the establishment and application of the great laws of thermo-dynamics, or, as it is often called, the mechanical theory of heat. The first law, which asserts that heat and mechanical work can be transformed one into the other at a certain fixed rate, is now well understood by every student of physics, and the number expressing the mechanical equivalent of heat resulting from the experiments of Joule has been confirmed by the researches of others, and especially of Rowland. But the second law, which practically is even more important than the first, is only now beginning to receive the full appreciation due to it. One reason of this may be found in a not unnatural confusion of ideas. Words do not always lend themselves readily to the demands that are made upon them by a growing science, and I think that the almost unavoidable use of the word equivalent in the statement of the first law is partly responsible for the little attention that is given to the second. For the second law so far contradicts the usual statement of the first, as to assert that equivalents of heat and work are not of equal value. While work can always be converted into heat, heat can only be converted iuto work under certain limitations. For every practical purpose the work is worth the most, and when we speak of equivalents, we use the word in the same sort of special sense as that in which chemists speak of equivalents of gold and iron. The second law teaches us that the real value of heat, as a source of mechanical power, depends upon the temperature of the body in which it resides; the hotter the body in relation to its surroundings, the more available the heat.

In order to see the relations which obtain between the first and the second law of thermo-dynamics, it is only necessary for us to glance at the theory of the steam-engine. Not many years ago calculations were plentiful demonstrating the inefficiency of the steam-engine on the basis of a comparison of the work actually got out of the engine with the mechanical equivalent of the heat supplied to the boiler. Such calculations took into account only the first law of thermo-dynamics, which deals with the equivalents of heat and work, and have very little bearing upon the practical question of efficiency, which requires us to have regard also to the second law. According to that law the fraction of the total energy which can be converted into work depends upon the relative temperatures of the boiler and condenser; and it is, therefore, manifest that, as the temperature of the boiler can not be raised indefinitely, it is impossible to utilize all the energy which, according to the first

law of thermo-dynamics, is resident in the coal.

On a sounder view of the matter, the efficiency of the steam-engine is found to be so high that there is no great margin remaining for improvement. The higher initial temperature possible in the gas-engine opens out much wider possibilities, and many good judges look forward to a time when the steam-engine will have to give way to its younger rival.

To return to the theoretical question, we may say with Sir W. Thomson that, though energy can not be destroyed, it ever tends to be dissipated, or to pass from more available to less available forms. No one who has grasped this principle can fail to recognize its immense importance in the system of the universe. Every change, chemical, thermal, or mechanical—which takes place, or can take place, in Nature, does so, at the cost of a certain amount of available energy. If, therefore, we wish to inquire whether or not a proposed transformation can take place, the question to be considered is whether its occurrence would involve dissipation of energy. If not, the transformation is (under the circumstances of the case) absolutely excluded. Some years ago, in a lecture at the Royal Institution, I endeavored to draw the attention of chemists to the importance of the principle of dissipation in relation to their science, pointing out the error of the usual assumption that a general criterion is to be found in respect of the development of heat. For example, the solution of a salt in water is, if I may be allowed to phrase, a downhill transformation. It involves dissipation of energy, and can therefore go forward; but in many cases it is associated with the absorption rather than with the development of heat. I am glad to take advantage of the present opportunity in order to repeat my recommendation, with an emphasis justified by actual achievement. The foundations laid by Thomson now bear an edifice of no mean proportions, thanks to the labors of several physicists, among whom must be especially mentioned Willard Gibbs and Helmholtz. The former has elaborated a theory of the equilibrium of heterogeneous substances, wide in its principles, and we can not doubt far-reaching in its consequences. In a series of masterly papers Helmholtz has developed the conception of *free energy* with very important applications to the theory of the galvanic cell. He points out that the mere tendency to solution bears in some cases no small proportion to the affinities more usually reckoned chemical, and contributes largely to the total electromotive force. Also in our own country Dr. Alder Wright has published some valuable experiments relating to the subject.

From the further study of electrolysis we may expect to gain improved views as to the nature of the chemical reactions, and of the forces concerned in bringing them about. I am not qualified—I wish I were—to speak to you on recent progress in general chemistry. Perhaps my feelings towards a first love may blind me, but I can not help thinking that the next great advance, of which we have already some foreshadowing, will come on this side. And if I might without presumption venture a word of recommendation, it would be in favor of a more minute study of the simpler chemical phenomena.

Under the head of scientific mechanics it is principally in relation to fluid motion that advances may be looked for. In speaking upon this subject I must limit myself almost entirely to experimental work. Theoretical hydrodynamics, however important and interesting to the mathematician, are eminently unsuited to oral exposition. All I can do to attenuate an injustice, to which theorists are pretty well accustomed, is to

refer you to the admirable reports of Mr. Hicks, published under the auspices of this Association.

The important and highly practical work of the late Mr. Froude in relation to the propulsion of ships is doubtless known to most of you. Recognizing the fallacy of views then widely held as to the nature of the resistance to be overcome, he showed to demonstration that, in the case of fair-shaped bodies, we have to deal almost entirely with resistance dependent upon skin friction, and at high speeds upon the generation of surface-waves by which energy is carried off. At speeds which are moderate in relation to the size of the ship, the resistance is practically dependent upon skin friction only. Although Prof. Stokes and other mathematicians had previously published calculations pointing to the same conclusion, there can be no doubt that the view generally entertained was very different. At the first meeting of the Association which I ever attended, as an intelligent listener, at Bath in 1864, I well remember the surprise which greeted a statement by Rankine that he regarded skin friction as the only legitimate resistance to the progress of a well-designed ship. Mr. Froude's experiments have set the question at rest in a manner satisfactory to those who had little confidence in theoretical prevision.

In speaking of an explanation as satisfactory in which skin friction is accepted as the cause of resistance, I must guard myself against being supposed to mean that the nature of skin friction is itself well understood. Although its magnitude varies with the smoothness of the surface, we have no reason to think that it would disappear at any degree of smoothness consistent with an ultimate molecular structure. That it is connected with fluid viscosity is evident enough, but the *modus operandi* is still obscure.

Some important work bearing upon the subject has recently been published by Prof. O. Reynolds, who has investigated the flow of water in tubes as dependent upon the velocity of motion and upon the size of the bore. The laws of motion in capillary tubes, discovered experimentally by Poiseuille, are in complete harmony with theory. The resistance varies as the velocity, and depends in a direct manner upon the constant of viscosity. But when we come to the larger pipes and higher velocities with which engineers usually have to deal, the theory which presupposes a regularly stratified motion evidently ceases to be applicable, and the problem becomes essentially identical with that of skin friction in relation to ship propulsion. Prof. Reynolds has traced with much success the passage from the one state of things to the other, and has proved the applicability under these complicated conditions of the general laws of dynamical similarity as adapted to viscous fluids by Prof. Stokes. In spite of the difficulties which beset both the theoretical and experimental treatment, we may hope to attain before long to a better understanding of a subject which is certainly second to none in scientific as well as practical interest.

As also closely connected with the mechanics of viscous fluids, I must not forget to mention an important series of experiments upon the friction of oiled surfaces, recently executed by Mr. Tower for the Institution of Mechanical Engineers. The results go far towards upsetting some ideas hitherto widely admitted. When the lubrication is adequate, the friction is found to be nearly independent of the load, and much smaller than is usually supposed, giving a coefficient as low as 1/1000. When the layer of oil is well formed, the pressure between the solid surfaces is really borne by the fluid, and the work lost is spent in

shearing, that is, in causing one stratum of the oil to glide over another.

In order to maintain its position, the fluid must possess a certain degree of viscosity, proportionate to the pressure; and even when this condition is satisfied, it would appear to be necessary that the layer should be thicker on the ingoing than on the outgoing side. We may, I believe, expect from Prof. Stokes a further elucidation of the processes involved. In the meantime, it is obvious that the results already obtained are of the utmost value, and fully justify the action of the Institution in devoting a part of its resources to experimental work. We may hope indeed that the example thus wisely set may be followed by other public bodies associated with various departments of industry.

I can do little more than refer to the interesting observations of Prof. Darwin, Mr. Hunt, and Mr. Forel on ripplemark. The processes concerned would seem to be of a rather intricate character, and largely dependent upon fluid viscosity. It may be noted indeed that most of the still obscure phenomena of hydro-dynamics require for their elucidation a better comprehension of the laws of viscous motion. The subject is one which offers peculiar difficulties. In some problems in which I have lately been interested, a circulating motion presents itself of the kind which the mathematician excludes from the first when he is treating of fluids destitute altogether of viscosity. The intensity of this motion proves, however, to be independent of the coefficient of viscosity, so that it can not be correctly dismissed from consideration as a consequence of a supposition that the viscosity is infinitely small. The apparent breach of continuity can be explained, but it shows how much care is needful in dealing with the subject, and how easy it is to fall into error.

The nature of gaseous viscosity, as due to the diffusion of momentum, has been made clear by the theoretical and experimental researches of Maxwell. A flat disk moving in its own plane between two parallel solid surfaces is impeded by the necessity of shearing the intervening layers of gas, and the magnitude of the hindrance is proportional to the velocity of the motion and to the viscosity of the gas, so that under similar circumstances this effect may be taken as a measure, or rather definition, of the viscosity. From the dynamical theory of gases, to the development of which he contributed so much, Maxwell drew the startling conclusion that the viscosity of a gas should be independent of its density,—that within wide limits the resistance to the moving disk should be scarcely diminished by pumping out the gas, so as to form a partial vacuum. Experiment fully confirmed this theoretical anticipation—one of the most remarkable to be found in the whole history of science, and proved that the swinging disk was retarded by the gas, as much when the barometer stood at half an inch as when it stood at thirty inches. It was obvious, of course, that the law must have a limit, that at a certain point of exhaustion the gas must begin to lose its power; and I remember discussing with Maxwell, soon after the publication of his experiments, the whereabouts of the point at which the gas would cease to produce its ordinary effect. His apparatus, however, was quite unsuited for high degrees of exhaustion, and the failure of the law was first observed by Kundt and Warburg, at pressures below 1 mm. of mercury. Subsequently the matter has been thoroughly examined by Crookes, who extended his observations to the highest degrees of exhaustion as measured by MacLeod's gauge. Perhaps the most remarkable results relate to hydrogen. From the atmospheric pressure of 760 mm. down to about ½ mm. of mercury the viscosity is sensibly constant. From this point to the highest vacua, in which less than one-

millionth of the original gas remains, the coefficient of viscosity drops down gradually to a small fraction of its original value. In these vacua Mr. Crookes regards the gas as having assumed a different, ultra-gaseous condition; but we must remember that the phenomena have relation to the other circumstances of the case, especially the dimensions of the vessel, as well as to the condition of the gas.

Such an achievement as the prediction of Maxwell's law of viscosity has of course drawn increased attention to the dynamical theory of gases. The success which has attended the theory in the hands of Clausius, Maxwell, Boltzmann, and other mathematicians, not only in relation to viscosity, but over a large part of the entire field of our knowledge of gases, proves that some of its fundamental postulates are in harmony with the reality of Nature. At the same time it presents serious difficulties; and we can not but feel that, while the electrical and optical properties of gases remain out of relation to the theory, no final judgment is possible. The growth of experimental knowledge may be trusted to clear up many doubtful points, and a younger generation of theorists will bring to bear improved mathematical weapons. In the meantime we may fairly congratulate ourselves on the possession of a guide which has already conducted us to a position which could hardly otherwise have been attained.

In optics attention has naturally centered upon the spectrum. The mystery attaching to the invisible rays lying beyond the red has been fathomed to an extent that, a few years ago, would have seemed almost impossible. By the use of special photographic methods Abney has mapped out the peculiarities of this region with such success that our knowledge of it begins to be comparable with that of the parts visible to the eye. Equally important work has been done by Langley, using a refined invention of his own based upon the principle of Siemens' pyrometer. This instrument measures the actual energy of the radiation, and thus expresses the effects of various parts of the spectrum upon a common scale, independent of the properties of the eye and of sensitive photographic preparations. Interesting results have also been obtained by Becquerel, whose method is founded upon a curious action of the ultra-red rays in enfeebling the light emitted by phosphorescent substances. One of the most startling of Langley's conclusions relates to the influence of the atmosphere in modifying the quality of solar light. By the comparison of observations made through varying thicknesses of air he shows that the atmospheric absorption tells most upon the light of high refrangibility; so that to an eye situated outside the atmosphere the sun would present a decidedly bluish tint. It would be interesting to compare the experimental numbers with the law of scattering of light by small particles given some years ago as the result of theory. The demonstration by Langley of the inadequacy of Cauchy's law of dispersion to represent the relation between refrangibility and wave-length in the lower part of the spectrum must have an important bearing upon optical theory.

The investigation of the relation of the visible and ultra-violet spectrum to various forms of matter has occupied the attention of a host of able workers, among whom none has been more successful than my colleagues at Cambridge, Profs. Liveing and Dewar. The subject is too large both for the occasion and for the individual, and I must pass it by. But, as more closely related to optics proper, I can not resist recalling to your notice a brilliant application of the idea of Doppler to the discrimination of the origin of certain lines observed in the solar spectrum. If a vibrating body have

a general motion of approach or recession, the waves emitted from it reach the observer with a frequency which in the first case exceeds, and in the second case falls short of, the real frequency of the vibrations themselves. The consequence is that, if a glowing gas be in motion in the line of sight, the spectral lines are thereby displaced from the position that they would occupy were the gas at rest —a principle which, in the hands of Huggins and others, has led to a determination of the motion of certain fixed stars relatively to the solar system. But the sun is itself in rotation, and thus the position of a solar spectral line is slightly different according as the light comes from the advancing or from the retreating limb. This displacement was, I believe, first observed by Thollon; but what I desire now to draw attention to is the application of it by Cornu to determine whether a line is of solar or atmospheric origin. For this purpose a small image of the sun is thrown upon the slit of the spectroscope, and caused to vibrate two or three times a second, in such a manner that the light entering the instrument comes alternately from the advancing and retreating limbs. Under these circumstances a line due to absorption within the sun appears to tremble, as the result of slight alternately opposite displacements. But if the seat of the absorption be in the atmosphere it is a matter of indifference from what part of the sun the light originally proceeds, and the line maintains its position in spite of the oscillation of the image upon the slit of the spectroscope. In this way Cornu was able to make a discrimination which can only otherwise be effected by a difficult comparison of appearances under various solar altitudes.

The instrumental weapon of investigation, the spectroscope itself, has made important advances. On the theoretical side, we have for our guidance the law that the optical power in gratings is proportional to the total number of lines accurately ruled, without regard to the degree of closeness, and in prisms that it is proportional to the thickness of glass traversed. The magnificent gratings of Rowland are a new power in the hands of the spectroscopist, and as triumphs of mechanical art seem to be little short of perfection. In our own report for 1882 Mr. Mallock has described a machine, constructed by him, for ruling large diffraction gratings, similar in some respects to that of Rowland.

The great optical constant, the velocity of light, has been the subject of three distinct investigations by Cornu, Michelson, and Forbes. As may be supposed, the matter is of no ordinary difficulty, and it is therefore not surprising that the agreement should be less decided than could be wished. From their observations, which were made by a modification of Fizeau's method of the toothed wheel, Young and Forbes drew the conclusion that the velocity of light *in vacuo* varies from color to color, to such an extent that the velocity of blue light is nearly 2 per cent. greater than that of red light. Such a variation is quite opposed to existing theoretical notions, and could only be accepted on the strongest evidence. Mr. Michelson, whose method (that of Foucault) is well suited to bring into prominence a variation of velocity with wave-length, informs me that he has recently repeated his experiments with special reference to the point in question, and has arrived at the conclusion that no variation exists comparable with that asserted by Young and Forbes. The actual velocity differs little from that found from his first series of experiments, and may be taken to be 299,800 km. per second.

It is remarkable how many of the playthings of our childhood give rise to questions of the deepest scientific interest.

The top is, or may be, understood, but a complete comprehension of the kite and of the soap-bubble would carry us far beyond our present stage of knowledge. In spite of the admirable investigations of Plateau, it still remains a mystery why soapy water stands almost alone among fluids as a material for bubbles. The beautiful development of color was long ago ascribed to the interference of light, called into play by the gradual thinning of the film. In accordance with this view the tint is determined solely by the thickness of the film, and the refractive index of the fluid. Some of the phenomena are, however, so curious as to have led excellent observers like Brewster to reject the theory of thin plates, and to assume the secretion of various kinds of coloring matter. If the rim of a wine-glass be dipped in soapy water, and then held in a vertical position, horizontal bands soon begin to show at the top of the film, and extend themselves gradually downwards. According to Brewster these bands are not formed by the "subsidence and gradual thinning of the film," because they maintain their horizontal position when the glass is turned round its axis. The experiment is both easy and interesting; but the conclusion drawn from it can not be accepted. The fact is that the various parts of the film can not quickly alter their thickness, and hence when the glass is rotated they rearrange themselves in order of superficial density, the thinner parts floating up over, or through, the thicker parts. Only thus can the tendency be satisfied for the center of gravity to assume the lowest possible position.

When the thickness of a film falls below a small fraction of the length of a wave of light, the color disappears and is replaced by an intense blackness. Profs. Reinold and Rücker have recently made the remarkable observation that the whole of the black region, soon after its formation, is of uniform thickness, the passage from the black to the colored portion being exceedingly abrupt. By two independent methods they have determined the thickness of the black film to lie between seven and fourteen millionths of a millimeter; so that the thinnest films correspond to about one-seventieth of a wave-length of light. The importance of these results in regard to the molecular theory is too obvious to be insisted upon.

The beautiful inventions of the telephone and phonograph, although in the main dependent upon principles long since established, have imparted a new interest to the study of acoustics. The former, apart from its uses in every-day life, has become in the hands of its inventor, Graham Bell, and of Hughes, an instrument of first-class scientific importance. The theory of its action is still in some respects obscure, as is shown by the comparative failure of the many attempts to improve it. In connection with some explanations that have been offered, we do well to remember that molecular changes in solid masses are inaudible in themselves, and can only be manifested to our ears by the generation of a to-and-fro motion of the external surface extending over a sensible area. If the surface of the solid remains undisturbed, our ears can tell us nothing of what goes on in the interior.

In theoretical acoustics progress has been steadily maintained, and many phenomena which were obscure twenty or thirty years ago, have since received adequate explanation. If some important practical questions remain unsolved, one reason is that they have not yet been definitely stated. Almost everything in connection with the ordinary use of our senses presents peculiar difficulties to scientific investigation. Some kinds of information with regard to their surroundings are of such paramount importance to successive generations of living

beings, that they have learned to interpret indications which, from a physical point of view, are of the slenderest character. Every day we are in the habit of recognizing, without much difficulty, the quarter from which a sound proceeds, but by what steps we attain that end has not yet been satisfactorily explained. It has been proved that when proper precautions are taken we are unable to distinguish whether a pure tone (as from a vibrating tuning-fork held over a suitable resonator) comes to us from in front or from behind. This is what might have been expected from an *a priori* point of view; but what would not have been expected is that with almost any other sort of sound, from a clap of the hands to the clearest vowel sound, the discrimination is not only possible, but easy and instinctive. In these cases it does not appear how the possession of two ears helps us, though there is some evidence that it does; and even when sound comes to us from the right or left, the explanation of the ready discrimination which is then possible with pure tones is not so easy as might at first appear. We should be inclined to think that the sound was heard much more loudly with the ear that is turned towards than with the ear that is turned from it, and that in this way the direction was recognized. But if we try the experiment we find that, at any rate with notes near the middle of the musical scale, the difference of loudness is by no means so very great. The wave-lengths of such notes are long enough in relation to the dimensions of the head to forbid the formation of anything like a sound shadow in which the averted ear might be sheltered.

In concluding this imperfect survey of recent progress in physics, I must warn you emphatically that much of great importance has been passed over altogether. I should have liked to speak to you of those far-reaching speculations, especially associated with the name of Maxwell, in which light is regarded as a disturbance in an electro-magnetic medium. Indeed, at one time I had thought of taking the scientific work of Maxwell as the principal theme of this address. But, like most men of genius, Maxwell delighted in questions too obscure and difficult for hasty treatment, and thus much of his work could hardly be considered upon such an occasion as the present. His biography has recently been published, and should be read by all who are interested in science and in scientific men. His many-sided character, the quaintness of his humor, the penetration of his intellect, his simple but deep religious feeling, the affection between son and father, the devotion of husband to wife, all combine to form a rare and fascinating picture. To estimate rightly his influence upon the present state of science, we must regard not only the work that he executed himself, important as that was, but also the ideas and the spirit which he communicated to others. Speaking for myself as one who in a special sense entered into his labors, I should find it difficult to express adequately my feeling of obligation. The impress of his thoughts may be recognized in much of the best work of the present time. As a teacher and examiner he was well acquainted with the almost universal tendency of uninstructed minds to elevate phrases above things: to refer, for example, to the principle of the conservation of energy for an explanation of the persistent rotation of a fly-wheel, almost in the style of the doctor in "Le Malade Imaginaire," who explains the fact that opium sends you to sleep by its soporific virtue. Maxwell's endeavor was always to keep the facts in the foreground, and to his influence, in conjunction with that of Thomson and Helmholtz, is largely due that elimination of unnecessary hypothesis which is one of the distinguishing characteristics of the science of the present day.

In speaking unfavorably of superfluous hypothesis let me not be misunderstood. Science is nothing without generalizations. Detached and ill-assorted facts are only raw material, and in the absence of a theoretical solvent have but little nutritive value. At the present time and in some departments the accumulation of material is so rapid that there is danger of indigestion. By a fiction as remarkable as any to be found in law, what has once been published, even though it be in the Russian language, is usually spoken of as "known," and it is often forgotten that the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory. In this matter we are greatly dependent upon annual reports and abstracts, issued principally in Germany, without which the search for the discoveries of a little-known author would be well-nigh hopeless. Much useful work has been done in this direction in connection with our Association. Such critical reports as those upon hydrodynamics, upon tides, and upon spectroscopy, guide the investigator to the points most requiring attention, and in discussing past achievements contribute in no small degree to future progress. But, though good work has been done, much yet remains to do.

If, as is sometimes supposed, science consisted in nothing but the laborious accumulation of facts, it would soon come to a standstill, crushed, as it were, under its own weight. The suggestion of a new idea, or the detection of a law, supersedes much that had previously been a burden upon the memory, and by introducing order and coherence facilitates the retention of the remainder in an available form. Those who are acquainted with the writings of the older electricians will understand my meaning when I instance the discovery of Ohm's law as a step by which the science was rendered easier to understand and to remember. Two processes are thus at work side by side, the reception of new material and the digestion and assimilation of the old; and as both are essential, we may spare ourselves the discussion of their relative importance. One remark, however, should be made. The work which deserves, but I am afraid does not always receive, the most credit, is that in which discovery and explanation go hand in hand, in which not only are new facts presented, but their relation to old ones is pointed out.

In making one's self acquainted with what has been done in any subject, it is good policy to consult first the writers of highest general reputation. Although in scientific matters we should aim at independent judgment, and not rely too much upon authority, it remains true that a good deal must often be taken upon trust. Occasionally an observation is so simple and easily repeated, that it scarcely matters from whom it proceeds; but as a rule it can hardly carry full weight when put forward by a novice whose care and judgment there has been no opportunity of testing, and whose irresponsibility may tempt him to "take shots," as it is called. Those who have had experience in accurate work know how easily it would be to save time and trouble by omitting precautions and passing over discrepancies, and yet, even without dishonest intention, to convey the impression of conscientious attention to details. Although the most careful and experienced can not hope to escape occasional mistakes, the effective value of this kind of work depends much upon the reputation of the individual responsible for it.

In estimating the present position and prospects of experimental science, there is good ground for encouragement. The multiplication of laboratories gives to the younger generation opportunities such as have never existed before, and which ex-

cite the envy of those who have had to learn in middle life much that now forms part of an undergraduate course. As to the management of such institutions, there is room for a healthy difference of opinion. For many kinds of original work especially in connection with accurate measurement, there is need of expensive apparatus; and it is often difficult to persuade a student to do his best with imperfect appliances when he knows that by other means a better result could be attained with greater facility. Nevertheless it seems to me important to discourage too great reliance upon the instrument-maker. Much of the best original work has been done with the homeliest appliances; and the endeavor to turn to the best account the means that may be at hand develops ingenuity and resource more than the most elaborate determinations with ready-made instruments. There is danger otherwise that the experimental education of a plodding student should be too mechanical and artificial, so that he is puzzled by small changes of apparatus much as many school-boys are puzzled by a transposition of the letters in a diagram of Euclid.

From the general spread of a more scientific education we are warranted in expecting important results. Just as there are some brilliant literary men with an inability, or at least a distaste practically amounting to inability, for scientific ideas, so there are a few scientific tastes whose imaginations are never touched by merely literary studies. To save these from intellectual stagnation during several important years of their lives is something gained; but the thoroughgoing advocates of scientific education aim at much more. To them it appears strange, and almost monstrous, that the dead languages should hold the place they do in general education; and it can hardly be denied that their supremacy is the result of routine rather than of argument. I do not myself take up the extreme position. I doubt whether an exclusively scientific training would be satisfactory; and where there is plenty of time and a literary aptitude I can believe that Latin and Greek make a good foundation. But it is useless to discuss the question upon the supposition that the majority of boys attain either to a knowledge of the languages or to an appreciation of the writings of the ancient authors. The contrary is notoriously the truth; and the defenders of the existing system usually take their stand upon the excellence of its discipline. From this point of view there is something to be said. The laziest boy must exert himself a little in puzzling out a sentence with grammar and dictionary, while instruction and supervision are easy to organize and not too costly. But when the case is stated plainly, few will agree that we can afford so entirely to disregard results. In after life the intellectual energies are usually engrossed with business, and no further opportunity is found for attacking the difficulties which block the gateways of knowledge. Mathematics, especially, if not learned young, are likely to remain unlearned. I will not further insist upon the educational importance of mathematics and science, because with respect to them I shall probably be supposed to be prejudiced. But of modern languages I am ignorant enough to give value to my advocacy. I believe that French and German, if properly taught, which I admit they rarely are at present, would go far to replace Latin and Greek from a disciplinary point of view, while the actual value of the acquisition would, in the majority of cases, be incomparably greater. In half the time usually devoted without success to the classical languages, most boys could acquire a really serviceable knowledge of French and German. History and the serious

study of English literature, now shamefully neglected, would also find a place in such a scheme.

There is one objection often felt to a modernized education, as to which a word may not be without use. Many excellent people are afraid of science as tending towards materialism. That such apprehension should exist is not surprising, for unfortunately there are writers, speaking in the name of science, who have set themselves to foster it. It is true that among scientific men, as in other classes, crude views are to be met with as to the deeper things of Nature; but that the life-long beliefs of Newton, of Faraday, and of Maxwell are inconsistent with the scientific habit of mind is surely a proposition which I need not pause to refute. It would be easy, however, to lay too much stress upon the opinions of even such distinguished workers as these. Men who devote their lives to investigation cultivate a love of truth for its own sake, and endeavor instinctively to clear up, and not, as is too often the object in business and politics, to obscure, a difficult question. So far the opinion of a scientific worker may have a special value; but I do not think that he has a claim, superior to that of other educated men, to assume the attitude of a prophet. In his heart he knows that underneath the theories that he constructs there lie contradictions which he can not reconcile. The higher mysteries of being, if penetrable at all by human intellect, require other weapons than those of calculation and experiment.

Without encroaching upon grounds appertaining to the theologian and the philosopher, the domain of natural science is surely broad enough to satisfy the wildest ambition of its devotees. In other departments of human life and interest, true progress is rather an article of faith than a rational belief; but in science a retrograde movement is, from the nature of the case, almost impossible. Increasing knowledge brings with it increasing power, and great as are the triumphs of the present century, we may well believe that they are but a foretaste of what discovery and invention have yet in store for mankind. Encouraged by the thought that our labors can not be thrown away, let us redouble our efforts in the noble struggle. In the Old World and in the New, recruits must be enlisted to fill the place of those whose work is done. Happy should I be if, through this visit of the Association, or by any words of mine, a larger measure of the youthful activity of the West could be drawn into this service. The work may be hard, and the discipline severe, but the interest never fails, and great is the privilege of achievement.

THE UNITY OF MATHEMATICS

By Dr. JAMES BYRNIE SHAW
PROFESSOR OF MATHEMATICS, UNIVERSITY OF ILLINOIS

I. Introduction

Every successful work of art has unity: it is self-sufficient. Every particular work of art itself has unity. There is unity in architecture, in sculpture, in painting, in poetry, in music, in drama, in dancing, in mathematics. This unity is due to the central ideas which permeate the whole work. Works of art may be classified according to the objects with which they are concerned. Crosswise of this classification is that according to the central ideas which weave the objects together. The objects of mathematics may be arranged as numbers, figures, designs, harmonies, operators, algebras, processes and theories. Through these run the golden threads which unify them: Form, identity, invariance, dependence and ideality. Form exhibits the objects in some particular way; identity persists through all the changes in form; invariance is an identity in different objects; dependence is a net holding forms together; ideality is the source from which flow new objects. This is an ascending spiral which takes us to the level of a more expanded domain. These ideas are the life of mathematics, which produces its foliage and flowers.

Mind itself has these same ideas in its structure. From the shreds of experience we construct what we call the world. If we see it in a new light, from some new point of view, we still insist on its identity. Even before Parmenides philosophers were searching for the unchangeable essence of things. As things flowed into others, the ceaseless change emphasized by Heracleitos, dependencies or conditions were perceived, the mind needed the idea of functionality in order to organize the multitudinous swarms of consciousness. In the evolving forms of life creativity was at work in the natural world and the world of mind and spirit. New genii appeared. In the history of mathematics we find the record. And mathematics is so interwoven with life that its central ideas are also those of life. There is a unity of life and mathematics through these ideas. They are primeval gods, before all things and before the Fates. Born of chaos, they give birth to unity. They breathe life into the clay of isolated objects.

II. Form

If we try to think of a world without forms, imagination fails. If the world were completely nebular, an aggregation of whirling particles moving in unpredictable and haphazard routes, shifting their positions rapidly and ceaselessly, with whimsical approaches and no less whimsical departures, lagging speeds, followed by lightning flashes; no electron structures, no atomic structures, no cells, no space configurations; an infinitely rapid whirlwind of changing elements; a universe of consciousness without memory, no vision, a dizzy, spinning madness of consciousness; being for an instant, an infinitesimal of time, followed by utterly unlike being for other instants; in such a universe what sort of ideas could there be, what type of thinking? It might be a pleasant, everlasting, forever changing nirvana of delight without form. But number would not exist, for there could be no individuals, everything would fuse together. Geometry would not exist, for all shapes would vanish in the making. Tactic would not exist, for there would be only disarrangements.

Logic would not exist, for there could be no conclusions. There might indeed be the realization of the will-o'-the-wisp of philosophers—"a succession of states of consciousness." Isolated instants can lead nowhere, for they can never be connected by the bonds of duration. Continuity would be absent, and each instant would become an infinitesimal eternity.

Irregularity and bizarre outlines do not prohibit form. The ceaseless dance of Brownian particles does not eliminate form. Even the gnarled and writhing trunks of trees on the timberline of some storm-twisted peak have common elements of form, as do the wisps of cloud that wind around their bases. But instantaneous and fleeting states do prohibit form. Form is found wherever there are static phenomena, and also in transitions that are orderly. There is form in the patterns of mathematics and also in its motricities.

Each art produces its characteristic forms. Modern art insists on the essential importance of form. In architecture the massive forms of Egypt, solid pyramids and huge blocks piled up expressed the immortality of life. The columns and roofs of Greece expressed the enjoyment of the present life. There is a suggestion in the buttressed Gothic cathedrals which we may well ponder to-day as the buttresses of organized churches are crumbling. The steel and glass towers in modern cities express the highly technical character of modern life. In municipal buildings and new homes we find many desert buttes and mesas, expressing the ever-resurgent appeal of nature to man. The pipes of Pan express simplicity of life, and the operas of Wagner express the emotional stress of civilization. The rainbow phantoms of mobile color come from an expanded consciousness, a new outburst of spiritual life. Hypernumbers, non-euclidean geometry, infinitesimals, discontinuous functions, gave man new liberties.

Forms may be classified as ***irreducible, reducible, incidental, inclusive, synthetic, ensemble, limiting,*** and others. An irreducible form is an element from which we may start in the construction of other forms. In multiplication a prime number is irreducible, and with the primes we may compound all integers. But on the additive side a prime of the form $4N+1$ is reducible, for it is the sum of two squares. Additively any integer is the sum of not more than four squares, nor the sum of more than nine cubes. In this way squares and cubes become irreducible elements, although some squares are the sum of two or three other squares, and some cubes are the sum of fewer than nine other cubes. The roots of Galois normal equations are irreducible elements in the sense that any one may be used to construct polynomials in it which will give every number in the field of the conjugate set of roots. A dance-form may be irreducible as the icosahedral group. A fugue may be reducible as the net of fundamental regions of an automorphic function.

As example of incidental form we will choose a method of reasoning due to Kempe. If we consider a collection of individuals, I, which can be separated into two exclusive sets, A and $\overline{A}$, and also into two exclusive sets, B and $\overline{B}$, we may construct a collection of the individuals in the incident sets, A,B, and those in the incident sets, $\overline{A},\overline{B}$. This collection we represent by $A*B$. For instance, let I be all integers, A the even numbers, $\overline{A}$ the odd numbers, B the multiples of 3, $\overline{B}$ those congruent to 1 or -1, modulo three, then $A*B$ consists of integers congruent to $0, 1$, or -1, modulo 6.

We find an inclusive form in some simple geometric diagrams. We may choose a point anywhere on each of two opposite sides of a paralellogram, join each to the two opposite vertices. The pairs of lines will meet in points which are on a line through the intersection of

the diagonals. This is also true if we start with any quadrilateral, whether it has parallel sides or not. We may also choose four fixed points on a circle, ellipse, parabola or hyperbola, and two others anywhere on the curve, and we have a similar figure. In fact, all these forms are included in one, as particular cases of the Pascal hexagram. We find in analysis an inclusive form in the theory of linear operators, which gives a wide list of expansions. Finding inclusive forms is usually called generalization.

Metric geometry consists of synthetic forms, fusing together number and geometric form. Abstract groups synthesize the theory of integers and hypernumbers. An opera synthesizes the counterpoint of music and the action of a drama. The quatrains of Omar, the Mathematician, synthesize the fire of eternal youth and the ice of philosophy. Sandburg said that poetry is the achievement of the synthesis of hyacinths and biscuits. Realism is the synthesis of dreams and the rags of daily events. Idealism is the synthesis of aspirations and wisps of spiral nebulae. Actualization is the wedding of a beam of light and a chaos of dust-particles. Life knows how to synthesize creative spirit and the rhythms of wavicles. In the end all art is the synthesis of a vision and a medium of expression. The forms of mathematics are crystal flowers. Poetry creates silent music. Drama creates invisible rhythms. Architecture creates musical crystals. Sculpture creates sleeping life. Painting creates singing light. Color-music creates rainbow phantoms. Music creates ethereal flowers. Dancing creates radiant youth. Seraph and Merman may be wedded.

A limiting form is determined by an infinite or a very large collection. The characteristic curves of the differential equation $xdx + ydy = 0$ are an infinite set of concentric circles, which shrink upon the center as the limit form. The equation $xdy + ydx = 0$ gives an infinite set of rectangular hyperbolas which have as limit form the common perpendicular asymptotes. Mortality tables are limit forms from a very large number of individuals. Limit forms may have properties quite different from those of the determining set. A limit function determined by a set of continuous functions may be very discontinuous. A limit form may be included in the determining set or may be no part of it. The characteristic lines of a differential equation may be a system of straight lines and their envelope, or they may define other limit loci not given by the differential equation. Perhaps life, at least personal life, is a limit form tangent to, but not part of, the infinite succession of passing instants of being. Possibly Heracleitos had in mind the evanescent moving film of life, and Parmenides had in mind the limit form which we furnish as the real story. The flow of the swiftly vanishing present may be what we call subconsciousness, while consciousness is the accompanying limit form.

Form is the intellectual view we have of the particular mode of expression which the artist uses for his vision. He may change the medium and the form, leaving the vision the same. He may despair of ever finding an adequate expression for the beauty that haunts him. We can study the form he uses, which we usually call his style. Form itself has beauty. In the elegant presentations of Picard and Goursat analysis is beautiful. The aeroplane views of Klein, with wide horizons, and the swift intuitive penetrations of Poincaré to the heart of the problem are two types of beauty. Beauty should find her incarnation worthy of her, whether in mathematics or in life.

III. Identity

Form may change without a change in the object. There is an underlying iden-

tity. This is a frequent device in poetry. John Gould Fletcher says:

> Like spraying rockets
> My peonies shower
> Their glories on the night.
> Towards the impossible,
> Towards the inaccessible,
> Towards the ultimate,
> Towards the silence,
> Towards the eternal,
> These blossoms go.

In this he repeats in different forms the futility of expression in actualizing a spiritual insight. A wild-bird's cry and the beat of the sea may also take the form of a dance-ecstasy. A majestic procession of clouds across the sky may be identical with a nocturne of Debussy. Georgia O'Keeffe's "Music—black, blue, and green" is identical with an ecstatic rhapsody.

Twenty-four centuries ago Parmenides, poet-philosopher, insisted that what really is always has been and always will be. He said the never-ceasing flow of the philosophy of Heracleitos was an illusion. The real is permanent and abiding. Its protean forms merely veil the eternal identity. Modern philosophy is in confusion: for, while it insists upon the permanence of a substance variously called matter, energy, electron, positron, neutron, etc., yet it actually considers only a series of vanishing events, a swiftly changing film of happenings. If we return to the arts, we find they are expressing in some temporary form a reality called beauty. Beauty is not a thrill, it is a definite spiritual reality, every work of art expressing rhythm, order, symmetry, harmony, with form, identity, invariance, functionality and ideality shining through. In a dance we find

> An evanescent pattern on the sight,
> Beauty that lives an instant, to become a sister
> beauty and a new delight.

Mathematics would be nearly helpless without identities. We transmute our statements into other forms which will be more easily penetrated. Many theorems are of this nature. An isosceles triangle is also isogonal; four points joined in pairs, so that the two joins are equal and bisect each other, may also be joined so as to make a rectangle. A polyhedron with four vertices is a polyhedron with four faces. If we construct a rectangle divided into four equal rectangles, and around the center place four points symmetrically, we may repeat this diagram all over a plane. It is identical with the design of the important points of an elliptic function, and also with the design of an electric distribution produced by an infinite charged wire enclosed by an infinite rectangular prism of conducting material. Again if we consider the algebra of the Kempe triadic logic, we find it is identical with the algebra of a group generated by an infinity of commutative operators of order 2. This Kempe logic includes the usual logic of classes and propositions, but is more general, for in it we have expressions that represent collections X which consist of common elements of A and B, but we do not know whether or not there are any elements from $\overline{A}$ or $\overline{B}$. In the ordinary logic it is assumed that a collection I can be exactly split into collections A and $\overline{A}$, B and $\overline{B}$, which also means into AB, $\overline{A}$B, A$\overline{B}$, $\overline{AB}$. Any collection considered is definitely known to include one or more of these and to exclude the others. But in the Kempe logic we may have a collection X known to include one or more of these, but it is not known if it excludes or includes the others.

Cayley designed colored linkages whose routes would give an identical representation for any abstract group. As an example let us take the quaternion group which has eight members, given by combinations of A and B, where $A^4 = 1 = B^4$, $A^2 = B^2$, $BA = A^3B$. To make the diagram we use the edges of a cube. Those of the upper face are traversed positively

and may be colored yellow. The lower face has its edges colored yellow also and is traversed negatively as seen from above. The vertical edges are colored blue and traversed downwards. The diagonals are also colored blue and traversed from the bottom point towards the top. If we put in the diagonals of the faces, colored white, they will give AB or BA. Whatever vertex is used as the beginning, the quaternion group is completely represented by this linkage.

Identities are *heteromorphisms, automorphisms, isomorphisms, equivalences, conjugacies,* and others. A song without words is a heteromorphism. The statues of Aphrodite are automorphisms. Different ballet dances are isomorphisms. The temples of Philae, of Brahma, the cathedrals of Europe, the mosques of Morocco, are equivalent forms. If we express the irrationals of a Galois field in terms of one of the roots of the normal equation, the same expressions will serve to represent the field of irrationals in terms of another of the roots, but not the same irrationals. In conjugate forms the expressions based upon one element of the conjugate set are also expressions when the base is a different conjugate element. There are conjugate dance forms. In an equivalence the identity is in some property. Modulo 12 we may consider as equivalent 5,17,41. Every equivalence can be called a congruence. Isomorphism gives us a form different from the original but of identical significance. The Wedding March of Lohengrin is isomorphic to the Wedding March of Mendelssohn. The Ave Maria of Brahms is isomorphic to the Ave Maria of Schubert. An automorphism is an identity of form. For instance, 65 is the sum of two squares in two automorphic ways, 1^2+8^2 and 4^2+7^2. The cyclic group of order 8 may be generated by the powers of either A, A^3, A^5 or A^7.

Heteromorphisms are perhaps the most difficult to discover. We would not at first think of any connection between Kempe's logic and synthetic geometry in a plane. But Kempe shows that if we read $A*B=C$ as "C is between A and B," every theorem in the logic becomes a theorem in the synthetic geometry of intersections in a plane. The value of the use of vector algebra in relativity theories lies in the heteromorphism by which every product and every sum in the algebra corresponds to a law or an object in the physical theory. If this is known many theorems can be enunciated without experimental proof. Sometimes heteromorphisms in mathematical theories are called "interpretations," and if such a new interpretation is found we at once have an extensive addition to our knowledge.

Art creates heteromorphisms. The metaphor expresses a heteromorphism. Sandburg expresses an identity when he says: "Poetry is the tracing of a finite sound to the infinite point of its echoes." Mathematics is the tracing of a single instance to the infinite point of its echoes. Mathematics writes the music of the spheres, as Pythagoras said. Mathematics paints with the colors of endless spectra. Mathematics recites the odyssey of human thought, as shown by Brunschvig. Mathematics follows the rainbow to the pot of gold. Hypernumbers are ripples of consciousness expanding into an infinite universe. Processes create new reasonings out of the chaos of ideas. Descartes showed the identity of algebra and geometry, and Lie the identity of continuous groups and differential equations. Poincaré perceived in his study of automorphic functions their identity with non-euclidean geometry. Linear algebras show the identity in the structures of expansions in fundamental functions. Sylvester and Kronecker agreed on the identity of mathematics and poetry.

Form is a golden thread that weaves together the objects of life. Identity too

is a golden thread that weaves together the objects of life. Life is the process of maintaining an identity. Human personality is an identity.

> Think, then, you are Today what Yesterday
> You were—Tomorrow you shall not be less.

Not a goddess only has the inscription:

> I am that which is, has been, and shall be.

IV. Invariance

Invariance is the property an object has of remaining unchanged, although it is connected with another object that does change. In the tempered scale of music the numerical relations between the vibration numbers of the tones of a major chord or a minor chord remain unchanged whatever the dominant note. In a fugue the theme remains the same through all its various expressions. We are usually taught that we should develop an invariant character, one which through all vicissitudes is solid, unchanging, "to be depended upon." The flowing cloud which Stuart Pratt Sherman insisted upon as the ideal character, and the eternal youth that Omar talks about, are not invariant characters, at least not in the conventional sense. The philosopher's search for final and all-comprehending truth is a quest for the invariants of life. So far as we know, there are none. Perhaps the only invariant of life is the everlasting quest itself, and a universe built on invariants would soon be frozen into silent death. Even laws of physics can depend upon the time functionally, and are not invariant.

A differential equation has characteristic lines, and these are invariant. The equation $xdy - ydx = 0$ has for its lines the radii from the origin in all directions in the plane of x, y. If we change the variables to r and θ, it becomes $d\theta = 0$, giving the same lines. The parallelograms that circumscribe an ellipse have an invariant area. If we cut a circle by secants through a fixed point, the product of the segments is an invariant for all secants. As a line moves in Euclidean space its length is invariant. The sum of the angles of a plane triangle is invariant, but not so on a sphere. The prime factors of an integer are the same set, in whatever order they may be found.

Invariants may be *parts* of the changing objects, *properties* of it, *related objects* or *fundamental objects*. If we express quaternions in terms of i, j, k and then change to a new expression in terms of i', j', k', the scalar and the tensor of the quaternion will remain the same. These are *parts* of the quaternion. If we multiply an integer of the form $a^2 + b^2c$ by another of the same form, the product is also of the same form, which is an invariant *property*. If we transform a matrix by a non-singular matrix, the scalar coefficients of the Cayley-Hamilton equation are *related* invariant forms, which may be calculated from the constituents or coefficients of the matrix transformed.

The axioms, postulates and other basic forms upon which a branch of mathematics depends are fundamental, and are invariants. The basis for Euclidean geometry remains unchanged throughout its development. Sometimes we see the statement that mathematics is a vast tautology, all its theorems being merely restatements of the fundamental bases. But actually the theorems state much more than the bases. There is a synthesis involved. Klein in his Erlanger Programm asserted that any geometry is really the statement of the invariants of a particular group. But Klein did not mean to imply by this that the discovery of these invariants was a simple matter and of no great importance. He well knew the difficulties in developing a geometry, even if the group was given. It has taken centuries to arrive at the theorems of to-day in Euclidean geometry. Even the geometry of trilinear coordinates, called by Tait an "elegant

trifle," is open for many new theorems. An abstract group is something different from its incarnation in a Galois group. The polynomial operators which give us the forms for the conjugate roots in terms of a given root are not easy to find. Consider the group given by the equations $A^{10} = 1 = B^8$, $BA = A^3B^5$. It is quite elementary in its properties, but what are the 80 expressions for the roots of its normal equation in terms of a selected one? We may write out without much difficulty the groups of order 32, but what are their normal equations? A simple test by any one will convince him that a set of postulates arbitrarily given is far from giving a developed theory corresponding. Merely to give a basis for a theory is just as inadequate for the theorems as the construction of a foundation for a cathedral is for the sublime structure erected upon it.

Sometimes invariants are considered to be significant of objective realities. Geometric invariants correspond to geometric objects. Physical invariants correspond to physical objects. Biological invariants give us natural laws. Authority has long been an invariant of society with an objective power back of it: yet to-day it is vanishing and equality is taking its place. Belief in God or gods has been invariant in the race; does it mean an objective reality? Does human personality also create new groups in different eras to furnish new invariants? Where are the snows of yesteryear?

V. Functionality

Classical philosophy was concerned with the ideas we have considered thus far. Pythagoras was interested in the structure of all things as made of numbers. Parmenides was interested in identity. Plato's ideas were universal invariants. Heracleitos mused over the ceaseless flow, the becoming of things, the philosophy of change. In recent times this has been profoundly developed by Bergson. Modern science started a new philosophy: that of functionality, which includes "becoming." Science tries to determine the necessary conditions that underlie phenomena and hopes to arrive at sufficient conditions. Too often a necessary condition has been considered as sufficient. When it was found that certain glandular actions seemed to be necessary to the development of some of our human characteristics, it was hastily stated that they were sufficient. Heredity and environment are among the necessary conditions of life. Are they sufficient to account for Plato, Da Vinci, Shakespeare, Beethoven, Poincaré? Human personality is a function of heredity, physiology, environment—and of nothing else? Psychological events are functions of nervous events—and are there no other variables? What if in the flow of life there are no sufficient conditions, and, as Heracleitos asserted, we never step into the same stream twice!

One type of functionality is *correlation*, that of my shadow, which goes in and out with me. This is the relation of a projected figure to the initial figure. Reciprocation is also a correlation. If we find with reference to a fixed triangle the polars of three points, they make a triangle whose vertices will have the lines through the three points as polars. If we arrive at the original triangle this way, so as to have a self-polar triangle, we have an involutory correlation. An ideal romance is an involution. Correlation of human lives is called "getting adjusted to society."

Limit forms are functions of an *infinity* or a great *multitude* of variables. The calculus of variations and Volterra's functions of lines are of this kind. Social structures are limit forms arising from very many individuals. A cloud is a statistical function of a multitude of miniature balloons. The mortality curve is a function of 100,000 individuals. Moral laws are the compromises of

courses of action of various myriads of persons. Laws of physics to-day are statements of probabilities of what will happen in the interplay of a great number of whimsical particles. The past and the future, immediate and remote, condensed with the present, subjected to all the variations of differing individuals, give us a limit function called the norm, or law, of history. Life is the limit function of a rapidly arriving and dissolving cinema film, threaded on the fibers of the universe, suffused with the color of creative desire.

Dominant functions furnish values below which or above which lie the values of another function. For rapidly oscillating functions, dominant functions become very important. They have more latitude than limit functions. The dominants of certain sets of human actions are extremes of action which the actual actions may never reach. Those whose actions cross outside the dominant are called insane, criminal, fanatic or genius. The prediction of dominant functions of human action becomes necessary to all who would sway mankind.

Nascent functions are those of Heracleitos's "becoming." The events of the present moment determine those of the next moment. This is the type of functionality expressed in differential equations. The rate of inversion of sugar is in proportion to the amount still uninverted. Cooling has a rate determined by the temperature already attained. The next movement of the dancer is the outcome of the movement just finished. It has sometimes been assumed that in natural phenomena events were governed by nascent functions. Given a complete description of positions and velocities (and we may add, accelerations and fields) of all particles in the universe, we might thence determine forwards what the universe would be in 10000 A.D., or equally backwards, what it was in 10000 B.C. This kind of functionality is assumed by all who believe that dreams foretell coming events. Every instant is pregnant with what will be born the next instant. No undetermined event can happen. This deterministic view is opposed of course to that of creative evolution, which sees entirely new causes and results emerging.

Opposed to this philosophy we find on one hand physics, which has to discuss functions in which the events of tomorrow depend on those of to-day, but also on those of the yesterdays, in a direct way, and different from the mediation of time in between. What a non-magnetized piece of iron will do depends upon its history. Day before yesterday is not dead and buried, but reaches across today with ghostly fingers to affect tomorrow. The grandfathers eat sour grapes and the grandchildren's teeth are set on edge.

Biology contributes its opposition along with physics. Life depends upon more elements than heredity and environment. There are mutations which can not be thus accounted for. Some of these may be produced artificially by the action of the human intellect in arranging extraordinary conditions, like great heat or cold or x-rays. But the mere fact that it takes a keen laboratory experimenter to do this proves that impersonal environment and heredity were not sufficient. The most important conclusion of modern science is that we can never account for events by the data we are able to get. If we are so blind as to assume that we could succeed "if we knew all the data," the "appeal to ignorance," then we are too blind to do scientific work.

A most important functionality is *freedom* and the *creative* relation. A vision beckons us from the future. A nocturne of Debussy may scintillate with aspirations. A dance of Ruth St. Denis is a prophecy for the race. The monads of Leibniz will grow into a new calculus. Goldbach's conjectured theorem is a call

for another theory of integers. The hypernumbers of Dirac project physics into the relativity universe. Orthogonal functions lead to wave-mechanics. Quaternions took Hamilton into a new world of hypernumbers. Operational analysis was the guide for Heaviside through a wilderness. The martyr and the fanatic are functions of the future. To say that human actions are solely governed by the past is to ignore the most important things humans have done. Human action for to-day only is called opportunist, blind, short-sighted. There are also functions that are beyond the reach of time, are eternal, supernal. Functions, too, are golden threads of the web shot through the universe to hold it together.

VI. Ideality

This is the most important central principle. Through it mathematics becomes a fairy-land, where Merlin waves the magic wand, and strange new things come upon the stage. These are not evolutions from what went before, but are produced by a creative activity. They do not arise from any of the data of the senses. When long ago an unknown genius said, "let there be negative numbers," they were so far removed from sense experience that for centuries they were called fictive, and "people did not approve of them." They said: "How can numbers be less than nothing?" Later another genius said: "Let there be square roots for negative unity," and these are still called "imaginary." When the law of unique factorization needed to be extended to algebraic integers, Kummer said, "Let there be ideal numbers," and so it was. Lobachevsky said, "Let there be a geometry with many parallels through a point," and it came to pass. Riemann said, "Let there be no parallels," and it was so. Then Riemann waved his wand again and an infinity of new geometries based on infinitesimals came into existence, and these fictions are used to-day in the relativity theories to explain very real phenomena. Hamilton said, "Let there be endless imaginary numbers," and so it was. Fourier said, "Let there be expressions for functions made up of arbitrary pieces," and the theory of expansions began. Weierstrass said, "Let there be continuous non-derivable functions," and now we are far from the use of the eye in studying graphs. If electrons have positions determining such functions the whole of physics has to be rewritten. Darboux said, "Let there be discontinuous functions which between $x=a$ and $x=b$ will take every value between $f(a)$ and $f(b)$," and so it is. Peano said, "Let there be functions which will ultimately give every point inside a square," and we study them. Transcendentally crinkly curves are very curious. Brouwer said, "Let there be numbers which are neither rational nor yet irrational," and logic has been deprived of the law of excluded middle. We have seen logics created in which the law of identity has vanished. There are logics in which the law of contradiction has also gone. We have in every case been forced to revise our methods of thinking. And in every case the magic wand has created new beings which have dissolved complications of thought, removed absurdities and contradictions. The law of contradiction made it impossible to think of beings which were material and at the same time immaterial. Yet spirit and mind are just that. Freedom and determinism have to be attached to the human being, it has both qualities. We must think in terms like these or we end in dismay. We see the universe in a new light, we dispense with red rays and pass to yellow rays, blue rays, ultraviolet rays, x-rays, cosmic rays. Electrons and protons are both particles and wave-phenomena. Matter and energy

have merged. Clouds of particles may have laws but particles are whimsical. Everything is swiftly losing its identity and becoming something quite different. The cat has vanished, leaving only the grin.

Ideal objects arise sometimes from the creation of a *new class* which will make complete the possibility of solving an equation. This is a closure property. With algebraic irrationals and with complex numbers we may find roots for any algebraic equation in one variable x. With hypernumbers we can solve equations which have variables x, y, etc. A solution of $z^2-2wz+w^2+x^2+y^2+z^2=0$ is the quaternion $z=w+ix+jy+kz$. Galois ideals solve congruences. Points at infinity, imaginary points, lines at infinity, four-dimensional and N-dimensional geometries enable us to fill out our problems in space. Poincaré pointed out the rôle physics has played in suggesting new mathematical objects. Whenever Antaeus touches the earth he gains new strength.

Ideal objects may also be *direct creations* of a new and perhaps unwanted order. The infinitesimals of Leibniz are still objects of suspicion to many mathematicians. Non-Archimedean arithmetic is to be developed. The theory of integers needs new ideas for its ordering. Elements of real and not arithmetic continuity must be studied. What vistas will open to psychology when the mathematics of duration is developed? The vast regions of processes have not been visited. Of the 5 types of commutativity only one has been considered, and of the 175 types of associativity in general fields, only one is studied.

Merlin has been bound at various times by Viviane, who has used the logic Merlin himself created to knot him with cords. She is powerless, however, for whenever he thinks a new world, a new creation, with new laws and new objects, the old world ceases to be a prison. The ant that runs around inside a circular band is a prisoner, until he leaves his plane and goes into the third dimension over the prison wall into a new space. So long as mathematicians are enchanted by the magic formula, "Mathematics is symbolic logic and nothing else," so long is Merlin a prisoner. But when he calls upon the Queen of Beauty for new worlds he is set free.

For truly, as thou sayest, son, a Fairy King
And Fairy Queens have built the city, son;
They came from out a sacred mountain-cleft,
Towards the sunrise, each with harp in hand,
And built it to the music of their harps.

For, an ye heard a music, like enow
They are building still, seeing the city is built
To music, therefore never built at all,
And therefore built forever.

Life seizes time and space, the rhythm of energy and the flames of inspiration, weaving them into a rhapsody of music. Ideality is the living cord which creates the past, present and eternity. Dreams as imaginary as the square root of -1 or as fantastic as relativity space and time, are to-morrow powerful actualities. Life consists in the creation of ideal objects.

The primeval gods were born of chaos, but their immense power is hurrying the particles of chaos and the ripples of its ocean, its intense fields and its creative spirits, into the unity of a universe. Through the ages of human life mathematics has come to be the screen upon which we may glimpse this unity.

NATIONAL TRENDS IN NOBEL PRIZE AWARDS[1]

By HARRISON HALE
PROFESSOR OF CHEMISTRY, UNIVERSITY OF ARKANSAS

THE Nobel prize awards for 1936 which aroused much interest were:

Physics: joint award, Victor Franz Hess, Innsbruck University, Austria
Carl David Anderson, California Institute of Technology, Pasadena
Chemistry: Peter Joseph Wilhelm Debye, Kaiser Wilhelm Institute, Berlin
Physiology and Medicine: joint award, Otto Loewi, University of Graz, Austria
Henry Hallett Dale, Director, National Institute for Medical Research, London
Literature: Eugene Gladstone O'Neill, Sea Island, Georgia
Peace: Carlos Saavedra Lamas, Argentina

Besides these an award of the 1935 Peace Prize to Carl Ossietzky, a German, was also made.

When Alfred Bernhard Nobel, Russian chemist and manufacturer, provided in his will that the income from eight million dollars be used to award prizes in five fields of endeavor "without any regard to nationality" he established a yardstick of national achievement. Nobel died in 1896, and annual awards have been made by designated groups of distinguished Europeans since 1901 in the five fields of physics, chemistry, physiology and medicine, literature and peace.

Had an award in each field been made each year the total would now be 180. But in some years an award in a special field or fields has been omitted, so that the number through 1936 is 155. These have been distributed as shown in Table I.

Nineteen nations are represented, Argentine being the newest member of the group.

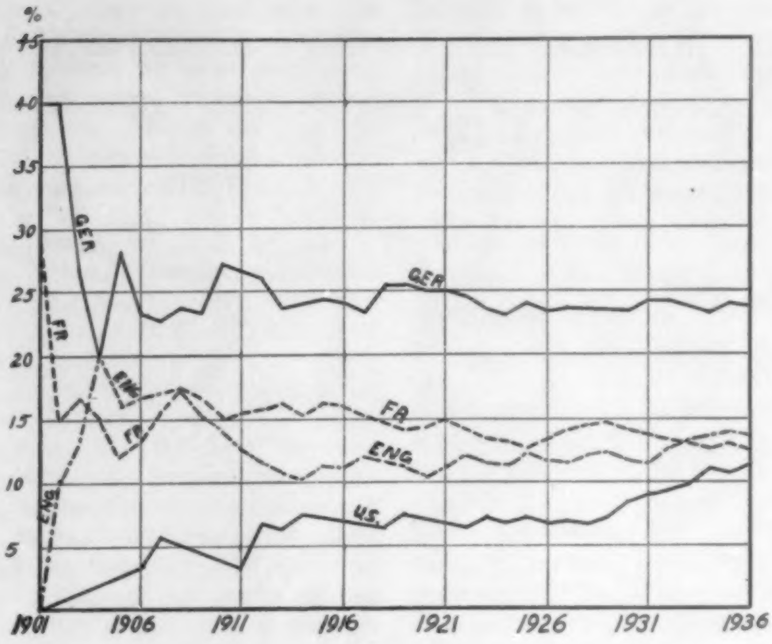
TABLE I
NATIONALITY OF NOBEL PRIZE WINNERS
1901–36

Country	Physics	Chemistry	Physiology Medicine	Literature	Peace	Awards 1901–18	Total
Germany	10	14	6	5	2	20	37
England	7	4[illegible]	3[illegible]	3	3[illegible]	9	21[illegible]
France	4	4	3[illegible]	4[illegible]	3[illegible]	11[illegible]	19[illegible]
United States	3	3	4	2	5[illegible]	5	17[illegible]
Sweden	2	2[illegible]	1	3	2	5[illegible]	10[illegible]
Switzerland	1	1	1	1	2[illegible]	4[illegible]	6[illegible]
Holland	3	1	1[illegible]	..	[illegible]	4[illegible]	6
Denmark	1	..	3	1	[illegible]	2[illegible]	5[illegible]
Austria	[illegible]	1	2[illegible]	..	1[illegible]	2[illegible]	5[illegible]
Belgium	..	..	1	1	2[illegible]	3[illegible]	4[illegible]
Norway	..	..	..	3	1[illegible]	1	4[illegible]
Italy	[illegible]	..	[illegible]	3	[illegible]	2[illegible]	4[illegible]
India	1	..	..	1	..	1	2
Poland	..	..	..	2	..	1	2
Russia	..	..	1	1	..	1	2
Spain	..	..	[illegible]	1[illegible]	..	1	2
Canada	..	..	1	..	..	..	1
Ireland	..	..	..	1	..	..	1
Argentina	..	..	..	..	1	..	1
International	..	..	..	..	1	1	1
Total	33	31	30	33	26	77	155
Distribution	10	8	14	15	14	16	18

All true science, literature and peace are international in scope. From a world view-point, then, it is interesting to ask what are the national trends in these awards. These may be seen in the graphs of Fig. 1, showing the cumulative percentages of total awards made, received by the four nations leading in number of awards.

Germany's preeminence is evident, and it is significant that the German percentage line has never been below 20, holding steadily between 20 and 28 of the total for 34 years. England likewise has maintained a steady percentage on a lower level than Germany, there being a slight upward trend from the low of 10.3 per cent. in 1914. For many years the percentage of France was next to that of Germany, but a slight downward trend

[1] See SCIENTIFIC MONTHLY, Vol. XL, pp. 167–169, February, 1935.


%
45
40
35
30
25
20
15
10
5
GER
GER
FR
FR
FR
ENG
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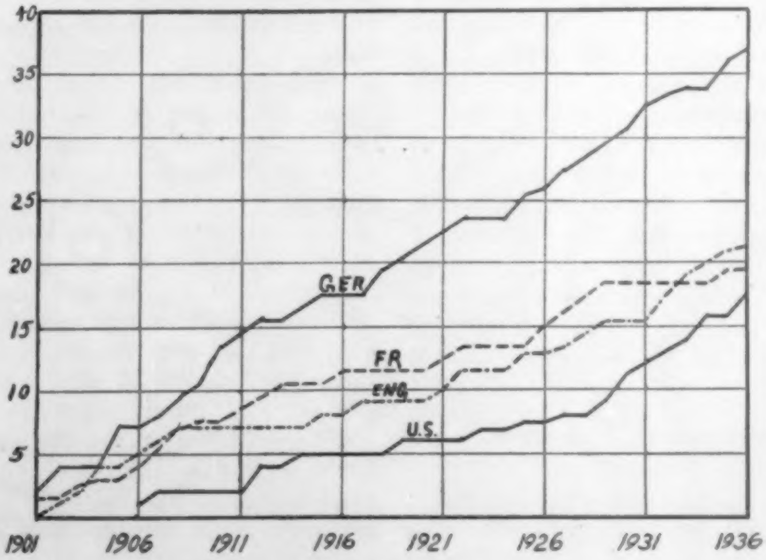
ENG
U.S.
1901
1906
1911
1916
1921
1926
1931
1936

FIG. 1


40
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GER
FR
ENG
U.S.
1901
1906
1911
1916
1921
1926
1931
1936

FIG. 2

has brought the curve below that of England.

The United States won no prize in the first five years until the award for Peace was made to Theodore Roosevelt in 1906. In 1911 its percentage was only 3.6, but since then the percentage has been higher, the trend being decidedly upward in the last eight years.

Another view-point of these awards is shown in the total number of Nobel prizes awarded to each of the four leading nations (Fig. 2).

The steady rise of the German line is impressive. The same is true of the lines for England and for France, but the rise is more gradual and not so regular and the absence of French awards from 1929 to 1934 causes the lines to cross. The original position of the United States in the early years was not only below Germany, France and England but below others also. As late as 1911 more awards had gone to Holland, Sweden, Switzerland and Italy as well. Awards had been made to twelve nations before such recognition came to America in 1906. Several horizontal periods of years of no award are evident. But recently its curve of awards rises rapidly.

In Table II of total awards over different periods it is seen that: (1) the United States has risen from a low fifth in the total awards in 1918 to a very close fourth in 1936; (2) since the world war as many awards have been made to Americans as to Englishmen, only those to Germans being greater; and that in awards made during the past eight years the United States has been the leader.

TABLE II
TOTAL AWARDS OVER DIFFERENT PERIODS

	Entire 1901–36	1901–18	1918–36	1929–36
Germany .	37	20	17	8½
England ..	21½	9	12½	7
France ...	19½	11½	8	2
U. S. A. ..	17½	5	12½	9½
Sweden ..	10½	5½	5	1½

THE BRAIN FROM FISH TO MAN. II

A SERIES OF CULMINATING PHASES IN EVOLUTION

By Dr. FREDERICK TILNEY

PROFESSOR OF NEUROLOGY, COLUMBIA UNIVERSITY

The Brain of Man

Although the human brain has made great advance in its weight when compared with the anthropoid brain, both absolutely and in relation to body weight, its chief superiority lies in the intricate complexity of its convolutional arrangement. The richness of its convolutions provides for a far more extensive spread of the neocortex. Its fissural pattern is more conspicuously Rolandic than in the anthropoids, but above all else is the obvious superiority of the frontal lobe. Superiority in this region of the neocortex carries with it what amounts to a new mastery of life. It is in this part of the brain that there gradually has emerged a cortical area essential to speech which in conjunction with other emergent areas in certain other regions of the cortex is essential to spoken language. Here also the neocortex makes more ample provision from the production and control of a greater, a more complex, a more highly potential range of skilled acts, which, like speech, may be regarded as something new in the animal kingdom. Or, if the newness of these acquisitions should be questioned, it is certainly true that they have done not a little to change the face of nature, to contend with forces which heretofore had not been challenged and to institute organizations, both material and spiritual, which are dependent upon the hand and brain of man. Properly speaking, this new mobilization of motor capacity, called neokinesis, should not be limited to the human race. In the strict sense it is the outgrowth of the neocortex and hence a characteristic of the mammal. But that it has had its culmination in man, as shown in the development of his many skilled activities and above all in his speech attainments, there can be no doubt.

The frontal lobe, often referred to clinically as a silent area of the brain, as a matter of fact is to be credited with most outspoken functions, not merely in the sphere of speech but in certain even more subtle attributes such as those connected with the regulation of the higher faculties, the development of the personality and the formation of all those associational memories which enter into personal experience and thus bespeak the degree of intellectual attainment. A similar and comparable convolutional expansion occurs in the occipital, parietal and temporal lobes of the human brain. These are features distinctive of man. But the accessions in the frontal region of the human cerebrum, in size, in prominence and in convolutional complexity overshadow all other advances. When, in the course of time, the brain has reached this level of evolutionary progress, the secret of its success in humanity was not alone that it had set on foot the Age of Man but far more that it had made possible an Age of the Frontal Lobe (Fig. 17).

Neocortical Horizons of the Primates

All these advances, leading up to man and culminating in his preeminence, took place in a single favored order, the primates. It was not because other orders in the great and essentially progressive class of mammals were lacking in the endowment of an ample neocortex that they failed to climb to the top.

Many of these other orders have most impressive looking hemispheres. But the neocortical design which failed to make ample provision for the frontal lobe was deficient in its ultimate prospects. Undoubtedly the primates' mode of living was provocative in making such provisions, for it must be apparent that the effect of arboreal habits had much to do with the development of the hand. The manner in which tree-life favored the development of hands and the erect posture is no longer a matter of debate. It is susceptible of exact demonstration. Whatever may have been the influences which caused certain members of the prehuman stock to desert the trees and live upon the ground, it is clear that one most important result of this change was the formation of the human foot. This structure was a solid foundation for the highest achievements of organic evolution. It ultimately produced an animal capable of dominating the world. It was responsible for all the extensive changes incident to the erect posture, for the rearrangements in the shape of the body, for the squaring of the shoulders and the broadening of the pelvis, for readjustments in the position of the heart and lungs, for new provisions in supporting the abdominal organs, for a reordering in the relation of the eyes to provide binocular, stereoscopic vision, for the modifications in the neck to suit the purposes of the most effective head movements, for freeing of the hands so that they might become highly constructive agents and, above all, for impressing upon the brain the effects of these many progressive advantages. If there could be any doubt that the hand and foot contributed in this decisive manner to the development of the brain, it might be asked, what would the brain have been if neither hand nor foot had made its appearance? It is apparent what limited advantages were acquired by animals equipped with hoofs or paws, flippers or wings. The brain responded to the requirements of these specialized organs. Nevertheless, such response was always and unmistakably the brain of an ungulate or a meat-eater, of a flying or of a swimming mammal. It was the brain of an animal of restricted behavior, as limited in the development of its intelligence as it was in the amplitude of its adjustments to life. It was particularly deficient in one great brain division which is the hallmark of all animals possessing hands. Summarized as briefly as possible, it may be said that what the brain owes to the hand and foot is the frontal lobe.

The history of the primates shows that they represent at least five definite horizons of progress. Beginning with Tarsius and Lemur, the Rolandic pattern first becomes apparent. The establishment of this pattern is accompanied by the earliest indications of the region forming the frontal lobe which, from this time onward, continues to gain in prominence. Going hand in hand with these advances, there has been a progressive intensification of functional localization in the neocortex. However diffuse such localization may have been in the cortex of lower mammals or even in the lower primates, there can be no question but that it became more and more precise in passing from one horizon to the next higher one. It is possible that the neocortex in lowly brains may have a certain degree of what has been called "equipotency," that one cortical area may act as a substitute for another area artificially removed. But the more humanoid the neocortex becomes, the more the possibilities of any such equipotency disappear until finally in man the clinician and especially the surgeon have learned to have the highest respect for the exact localization of function in the cortex.

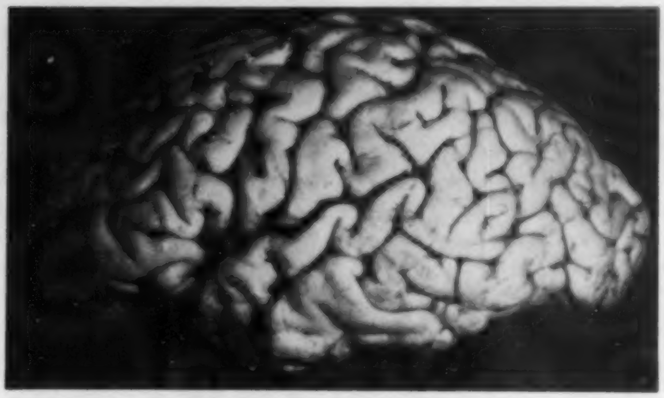


FIG. 17. LEFT HEMISPHERE OF A SCIENTIST AND SCHOLAR
BEQUEATHED TO THE WRITER FOR SPECIAL STUDY. THIS MAN, IN SPITE OF HIS SEVERAL OUTSTANDING TALENTS, WAS TONE-DEAF AND ENTIRELY LACKING IN MUSICAL APPRECIATION.

The Pyramidal and Extrapyramidal Systems

Thus far attention has been focused on the outer aspects of the brain. The internal structure of the organ now deserves consideration, particularly its groups of nerve cells, its cortical areas and the fibers uniting these regions or providing ultimate distribution of the nerve impulses. In some instances the general significance of these structures speaks for itself; in others the neural elements actually yield themselves to quantitative analysis.

Functionally, one outstanding feature of the brain is its control of motion. Two great systems of nerve fibers participate in this activity, namely, the pyramidal system and the extrapyramidal system. The term extrapyramidal motor system is in many ways unfortunate. I am in full accord with Ariens Kapper's view that in discussing this system in all submammalian classes it is necessary to include the whole central motor organization. The pyramidal system is entirely wanting in all vertebrates below the mammals, and hence all their movements and postural changes come under extrapyramidal control. Furthermore, the receptors dominating the extrapyramidal system must also be included, and thus this system embraces the entire brain of birds, reptiles, amphibia and fish.

In all mammals, including man, extrapyramidal function is more narrowly limited, either "justly or unjustly," to changes in motility and tonus associated with the activities of the corpus striatum, the corpus subthalamicum of Luys, the substantia nigra, the red nucleus and allied nuclei.

But more than this, it has been shown that the motor cortex sends controlling fibers to all these important nuclear aggregations. Because of this superimposed neocortical regulation, the mammalian extrapyramidal system is not in any sense the homologue of the corresponding system in birds, reptiles, amphibia and fish.

The advent of the neocortex in mammals subjected the ancient so-called extrapyramidal system to dominating influences which did not exist in submammalian classes.

In fishes motility is specifically controlled through the midbrain by afferent impulses arising from the labyrinthine and lateral-line organs in conjunction with visual and body sense impulses. The pathways involved in afferent conveyance are the spino-tectal, spino-mesencephalic and optic tracts. The efferent

pathways are the tecto-bulbar and tecto-spinal tracts. Endbrain influence in the production and guidance of motion is small or even doubtful.

In the more definitely water-living amphibia such as the salamander, conditions resemble those of the fish, but in frogs the lateral line nerves have disappeared, the auditory fibers have developed and the endbrain presents the most primitive part of the paleostriatum or basal ganglion (globus pallidus).

In reptiles the endbrain undergoes further expansion. Besides the paleostriatum (globus pallidus) these animals possess a neostriatum which is the primordium of the nucleus caudatus and putamen of the lenticular nucleus. Motor control is still mediated through the midbrain by way of the ansa lenticularis to the red nucleus. The neostriatum is in the afferent side of the arc and acts as a sensory correlating center.

In birds the plan is still the same, with the exception of the added mesostriatum. This nucleus is, in effect, the outer limb of the globus pallidus.

In mammals and man mediation of motor control is still, to some extent, by way of the midbrain. This control, however, is extensively supplemented by three new pathways from the neocortex, which, heretofore, were non-existent. These pathways are: (1) the cortico-spinal, pyramidal system; (2) the cortico-striatal system and (3) the cortico-ponto-cerebellar system, so that now motor control is exercised through the neocortex by way of the pyramidal and allied systems.

Considering the difficulties and inconsistencies inherent in the terms pyramidal and extrapyramidal, it might be advantageous to utilize some other terminology, especially in the submammalian classes of vertebrates in which the pyramidal system is entirely lacking. The two major systems for the control of motor activities are sufficiently distinct, both from the structural and functional points of view, to require most exact definition. One of them has great antiquity. Although it draws its motivating impulses from the entire field of sensory organization of the animal, it affords relatively limited brain mechanisms for the association and elaboration of these impulses. It operates without the more effective influences of a highly developed endbrain. As a system it is adequate for the regulation and direction of the behavior in fish, amphibians, reptiles and birds. The other motor system, present in mammals only, is of recent acquisition. It introduces a wholly new component in motor organization. Not only does it offer independent means for bringing into play the extensive and expansible influences of the neocortex, but it also subjects the older motor system to its far-reaching control. The so-called extrapyramidal motor system, because of its great age, might reasonably be called "*paleokinetic*," while the pyramidal system, by reason of its more recent and exclusively mammalian development, deserves the designation of "*neokinetic*." Distinction is thus clearly drawn between the motor characteristics of the mammals and those of all vertebrates which occupy positions below them in the phyletic scale.

Structural Culminations in the Brain Indicated by Coefficients of Internal Features

Numerous internal features of the brain bear witness to its evolutionary progress. In most instances these features are directly or indirectly connected with the development of neokinesis. Their values are estimated by planimetry, which makes it possible to establish comparative figures. Thus the percentage values of the pontile nuclei, the pyramid, the cerebral peduncle and inferior olivary body are shown in the tabulation of their planimetric coefficients. The first three of these structures are intimately connected with the neo-

cortex and are particularly associated with the development of neokinesis. The fourth structure, namely, the inferior olive, is less exclusively neokinetic, although it is involved in steadying the movements of the tongue, larynx, palate and lips. Its increasing value culminating in man is in all probability associated with the production of spoken language (Table II).

Planimetric coefficients derived from representatives of the five primate horizons indicate the advancing values of internal structures connected with the neocortex. The striking manner in which the value of the pyramidal system rises by graded stages from Tarsius to man points conclusively to the strides made in neokinetic development. The pontile nuclei and the cerebral peduncle reveal the progressive dominance of the neocortex in the control of behavior. The

TABLE II
PLANIMETRIC COEFFICIENTS OF THE PRIMATE BRAIN

	Man	Gorilla	Chimpanzee	Orang	Gibbon	Baboon	Macacus	Mycetes	Marmoset	Lemur	Tarsius
Pyramid	.183	.161	.172	.160	.138	.143	.147	.137	.064	.110	.032
Pontile nuclei ..	.550	.480	.400	.300	.200	.164	.150	.103	.095	.055	.057
Cerebral peduncle	.321	.187	.223	.110	.110	.190	.169	.144	.079	.086	.017
Inferior olive ...	.226	.186	.174	.172	.155	.125	.128	.120	.038	.060	.042
Nucleus dentatus	.176	.152	.136	.160	.134	.165	.155	.130	.077	.110	.059
Nucleus globosus.	.023	.0095	.018	.015	.020	.023	.014	.032	.050	.032	.037
Red nucleus	.128	.096	.086	.087	.051	.060	.057	.081	.044	.012	.034
Superior cerebellar peduncle ..	.088	.047	.047	.064	.063	.044	.046	.036	.048	.033	.032
Inferior colliculus	.070	.111	.132	.131	.130	.155	.175	.182	.210	.223	.337
Superior colliculus	.104	.140	.125	.124	.132	.173	.158	.161	.154	.140	.230
Nucleus of Goll..	.064	.086	.050	.048	.034	.086	.076	.131	.068	.041	.026
Nucleus of Burdach	.100	.081	.073	.093	.068	.065	.086	.113	.043	.049	.029
Nucleus of Deiters	.065	.072	.077	.054	.085	.060	.075	.114	.077	.082	.180
Nucleus of Schwalbe	.075	.070	.080	.055	.092	.095	.087	.090	.060	.045	.062

TABLE III
ENCEPHALIC INDICES OF EVOLUTIONAL SIGNIFICANCE

Animal	Volume index: Forebrain Per cent.	Volume index: Midbrain Per cent.	Volume index: Hindbrain Per cent.	Weight index: Forebrain Per cent.	Weight index: Midbrain Per cent.	Weight index: Hindbrain Per cent.
Index: 82 and above		**Hands Fingers Finger nails**				
Homo sapiens, modern man	88	1	11	87	1	12
Troglodytes gorilla, gorilla	84	2	14	84	2	14
Simia satyrus, orang-outang	83	5	12	83	5	12
Macacus rhesus, Indian monkey ...	83	2	15	84	2	14
Hylobates hoolock, gibbon	82	2	16	82	2	16
Callithrix jacchus, marmoset	83	2	15	83	2	15
Index: 70 to 80		**Paws Hoofs Claws**				
Canis familiaris, dog	80	7	13	80	5	15
Felis domestica, cat	77	6	17	75	4	21
Equus caballus, horse	80	2	18	80	2	18
Bos taurus, cattle	80	2	18	80	2	18
Camelus bachtr., camel	79	2	19	79	2	19
Elephas indicus, elephant	72	2	26	71	2	27
Myrmecophaga jub., giant ant-eater..	75	6	19	73	5	22
Bradypus tridact., three-toed sloth..	70	10	20	70	10	20
Index: 20 to 60		**Wings Fins Paddles**				
Rhea americana, ostrich	58	16	26	60	13	27
Aspidonectes ferox, soft-shelled turtle	57	15	28	53	20	27
Rana sylvatica, frog	..	..	..	21	37	42
Gadus morrhua, cod-fish	20	40	40	20	40	40
Squalus acanthias, dog-fish	..	..	..	23	27	50

rise of this superlative tissue of the body is also reflected in the waning prominence of the superior colliculus, the homologue of the optic lobe in lower vertebrates. Whereas the center of vision in birds, reptiles, amphibia and fish occupies this conspicuous lobe of the midbrain, by transference to the endbrain, it eventually finds more ample accommodation in the neocortex of the occipital region of the hemisphere.

Indices and Coefficients of External Cerebral Features

The relations of the forebrain, midbrain and hindbrain by weight and volume furnish an excellent idea of the advances made by vertebrates in the acquisition and development of neokinetic control over motor activities (Table III). Animals whose indices range from 20 to 60 per cent. possess no neocortex. Their motor control consequently lacks any pyramidal elements, and such animals meet the issues of life largely by wings, fins or paddle. In cases where the range is from 70 to 80 per cent. some degree of neocortex has developed and the pyramidal system has become operative. These animals make their way by paws, hoofs and claws. In the primates the indices run from 82 to 88 per cent., climaxing in man at the highest figure and indicating the extent to which neokinesis has been developed. These indices confined to the primates indicate the increases in the forebrain and their high value in man (Table IV).

More significant still are the comparative planimetric coefficients of surface areas of the neocortex from lower mammals through the anthropoids to man. The true meaning of this comparison is the relation of the frontal lobe to the other three lobes, T.P.O. (temporal-parietal-occipital). Beginning with a low mammal, the ant-eater, which has a coefficient of 9, and gradually ascending, the coefficient of 47 for the frontal lobe is eventually reached in man.

TABLE IV
Encephalic Indices

Animal	Encephalic index (per cent.)		
	Fore-brain	Mid-brain	Hind-brain
Lemur	81	5	14
Marmoset	80.5	0.5	19
Mycetes	81.6	4.8	13.6
Baboon	83	3	14
Macacus	84	2	14
Gibbon	81	3	16
Orang-Outang	83	5	12
Chimpanzee	83	5	12
Gorilla	84	1	14
Human	86–89	1	10–13

Cerebral Evidence Derived from the Extinct Races of Man

The brain had passed through certain preliminary stages long before man made his appearance on the scene. Its basic patterns had been perfected. Its most important mechanisms had been improved. In those preparatory days, all manner of animals inhabited the earth—fish, amphibians, reptiles, birds and mammals. They were the stepping stones of progress. When at length the first members of our family arrived, their brains were barely human and they themselves were most crude human beings. There was a certain triumph in their advent, however, for at last there were men. They were to inaugurate a new age which was to be called the Age of Man, and was to differ from all preceding ages by the steadily increasing products of human achievement. But the brain of these men was relatively small in its capacity and still unrefined in many of its structural details. Hundreds of thousands of years were necessary for such a brain as this to attain its highest efficiency. To most of us who are accustomed to reckon time as the hours between breakfast and dinner or at most as the proverbial three score years and ten, these long periods sound fabulous and fantastic. In contemplating the past our vision usually stops short at the beginning of history, five to six thousand years ago. Such a focus is unfortunately near-sighted. It leaves us insensitive to the much longer prehistoric period. Yet through all this unrecorded time, man

struggled upward to achieve those successes which at length established the Age of the Frontal Lobe. Much evidence of this vast prehistoric period is now available. It tells us of at least four extinct races of man. Carefully examined, it reveals what the early members of our family must have been when the long human journey first started.

In all his races, living and extinct, man constitutes the sixth family in the primate suborder, *Anthropoides* (manlike). This family is known as the *Homidae* (men of all types). The progenitors of the human family split off from a common anthropoid stock at some time in the Tertiary (Age of Mammals). At this critical juncture, variously estimated between 10,000,000 and 25,000,000 years ago, two great branches of the suborder parted company (Fig. 18). Thenceforth they developed independently of each other. The first branch from this common stem gave rise to human races. From the second branch arose the great modern anthropoid apes, including the orang outang, the chimpanzee and the gorilla.

The Java Ape-Man—Pithecanthropus Erectus

Probably the oldest, most primitive of extinct races is the ape-man of Java who, although definitely human, had many simian qualities. He possessed a head and face not unlike those of an ape, but his brain was nearly twice the size of any simian (940 cc). It was this great advantage which assured him an unassailable place as a member of the human family. The fossil remains of the ape-man were discovered in 1891 by a Dutch army surgeon, Dr. Eugen DuBois, who made the discovery on the Bengawan River in Central Java, where he found almost the entire skullcap of this primitive man. It is estimated that Pithecanthropus lived somewhere between 500,000 and 1,000,000 years ago (Fig. 19-A).

The striking feature about the brain of the ape-man is the great expansion which has taken place in the frontal lobe. Of even greater significance are the indications of a convolution in the lower portion of the frontal lobe on the left side. In all living men this convolution is associated with the control of spoken language. It seems probable therefore that the ape-man had acquired the powers of speech. This acquisition had a decisive bearing on the destiny of humanity.

If it were possible to catalogue the chief developmental changes which determined human emergence from lower levels of animal life they doubtless would appear in the following order:

(1) The development of the human foot upon which to establish the erect posture.
(2) The freeing of the hand in consequence of the erect posture for the purposes of human progress and success.
(3) The expansion of sight and hearing for better appreciation of the world and the most effective guidance of action.
(4) The development of speech.
(5) The establishment of human personality and the development of higher mental faculties.

All these changes were directly dependent upon the growth and higher specialization of the neocortex, particularly in the region of the frontal lobe. Most of these advancements were, to some degree, operative in the ape-man of Java.

The Dawn-Man of Piltdown, England—Eoanthropus Dawsoni

From certain flints, with many features indicating their use as instruments, it is held probable that there were primitive men living in England at a time earlier than that assigned to the ape-man of Java. Disputes about these early prehistoric Englishmen arise from the fact that no actual human remains of them have yet been found. This, fortunately, is not the case with the famous English dawn-man. This human fossil was found not many miles from the English Channel. The fossilized remnants consisted of a number of fragments of this extinct

Through the courtesy of the American Museum of Natural History. Drawing by Mr. E. S. Lewis.

FIG. 18. THE PRIMATE BRANCH OF THE VERTEBRATE FAMILY TREE AS PREPARED BY PROFESSOR GREGORY.

A B

FIG. 19. MODELS OF PREHISTORIC MEN

RECONSTRUCTED BY PROFESSOR J. H. MCGREGOR OF COLUMBIA UNIVERSITY AND REPRODUCED THROUGH HIS COURTESY. A, JAVA APE-MAN. B, PILTDOWN MAN.

man's skull. In December, 1912, Sir A. Smith-Woodward and Mr. Dawson presented to the Geological Society of London a reconstruction of the Piltdown skull. The announcement of this remarkable discovery made a deep stir in scientific circles. An unknown phase of early human existence was about to be revealed. The reconstructed skull impressed all who saw it as a strange blend of ape and man (Fig. 19-B). Some suggested that it was a missing link, for which the early followers of Darwin had earnestly sought. But whether this was the missing link or not, the Piltdown strata in Sussex told of a race of human beings who inhabited England long before history had made its feeblest beginnings. Dr. Smith-Woodward believes the fossil dated back to the early part of the Pleistocene period. Sir Arthur Keith and Professor Osborn give it far greater antiquity and assign it to some part of the Pliocene. Whatever the exact prehistoric era of the Piltdown fossil may be, it is clear that a primitive race of men lived in England thousands of years before Caesar's invasions, in fact ages before the ancient Celts or Goedelic Britons occupied the land. The Piltdown man is regarded by some as the direct ancestor of modern races; by others he is held to be an independent branch of the human family of quite unknown affiliations.

Several different brain-casts have been made from the reconstructed skull of the dawn-man of England. Such differences as exist in them do not contradict the fact that this brain was undeniably human and superior to that of the apeman of Java.

Neanderthal Man—Homo Primogenius

Man's first great epoch came in the Old Stone-Age (Paleolithic, which began 900,000 years ago). A new and sturdy race of men gained the upper hand in Europe. This race is known as the Neanderthals. The ancestry of these remarkable people is traced back to the Heidelberg man (Paleoanthropus) who appeared about 800,000 years ago and is

considered the first man of the Old Stone Age. The Neanderthals have a probable antiquity of 600,000 years. They were hunters and the first cave-dwellers. As flint workers they made and improved many implements. Their long period of human supremacy is characterized by definite culture periods, such as the Chellean, Acheulean and Mousterian periods (Fig. 20).

The scattered fossils of this famous race which have been found in many different parts of Europe all tell the story of an unusually powerful people. Their arms were long and muscular, their necks thick, their legs short and slightly bent at the knees. The Neanderthal had a low retreating forehead with heavy ridges of bone arching above the eyes. The jaws were heavy, the nose broad and flat, the chin receding. All these features must have given the Neanderthal man a brutish appearance. His brain, however, attests that far from being a lowly apelike creature he had many of the higher human attributes.

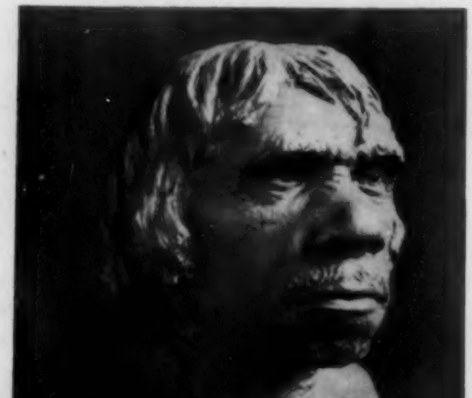


FIG. 20. MODEL OF NEANDERTHAL MAN RECONSTRUCTED ON THE SKULL FROM CHAPELLE-AUX SAINTS BY PROFESSOR J. H. MCGREGOR OF COLUMBIA UNIVERSITY AND REPRODUCED THROUGH HIS COURTESY.

The earliest discovery of these ancient people was made in 1848, when Lieutenant Flint found a Neanderthal skull in an old quarry at Gibraltar. These aggressive and productive people dominated Europe until well on toward the end of the Old Stone Age. The problem of their disappearance before the advance of a superior people has not yet been solved. The real secret in the failure of the old Neanderthal race and the success of the newcomers is doubtless to be found in the brain. It was the increased brain power of the Cromagnons which produced the supremacy of this last great race in the Old Stone Age. It was this power which gave Europe its first pioneers in art and which, for all mankind, opened the doors of creative imagination and appreciation of beauty in the world.

Cromagnon Man—Homo Sapiens

The Cromagnon has a probable antiquity of 50,000 years. He has a well-developed brain and frontal lobe of thoroughly modern type. He was an effective warrior and huntsman, but above all he was an artist. He employed and greatly refined the flint implements of the Old Stone Age and passed through successive cultural periods known as the Aurignacian, Solutrean, Magdalenian and Azilian. His chief contribution to human progress was the introduction and founding of art. He was the world's first great artist (Fig. 21).

The fate of the Cromagnon race was no exception to what had gone before or what would follow many times thereafter. Race after race, nation after nation rose, became master and passed into final decline.

As the day of Cromagnon ascendancy waned a new race invaded Europe. The Old Stone Age came to its end approximately 10,000 years ago with the advent of the more vigorous Neolithic man. With the introduction of agriculture, the

domestication of animals and the establishment of permanent abode, men of the New Stone Age contributed many of the essentials of modern life. These essentials included new ways of defending their claims and asserting their rights. Such new assertiveness quickly led to the more sanguinary Ages of Bronze and Iron, with their communal equipment for offense and defense. Its influences finally spread into historic times. Ultimately these more aggressive tendencies created all the armed camps which we are pleased to call civilization, ancient, medieval and modern. At the end of the New Stone Age all the direct ancestors of modern European races were established in Europe.

The dawn of history was followed by a procession of great events, which began in the early Egyptian dynasties. The development of Pharaonic culture, the regal splendors of Babylonia and Chaldea, the incomparable achievements of Greece and Rome followed in rapid succession. Each of these civilizations contributed to the development of the race. Then came the eclipse of the Dark Ages in medieval times and at length the brilliant light of the Renaissance, the illuminating influences of which have been carried forward in the accomplishments of modern times.

This is an inspiring picture of almost uninterrupted human progress. How readily it has been taken at its face value by the most gullible of living animals, *homo sapiens!* Man has been too deeply engrossed in his ancient glories and modern proficiencies to take a good look at himself. No longer than a quarter of a century ago there were reasons for the Caucasian's pride and self-assurance. Peace existed between the nations. Success filled every walk of life. Social order rested upon firm moral foundations. This was a human establishment upon which to rely. But ultimately this record of the white man brings us to a fateful midsummer afternoon in August, 1914. The race has been the victim of

FIG. 21. MODEL OF CROMAGNON MAN
RECONSTRUCTED ON THE SKULL FROM LES EYZIES, DORDOGNE, FRANCE, BY PROFESSOR J. H. MCGREGOR OF COLUMBIA UNIVERSITY AND REPRODUCED THROUGH HIS COURTESY.

many such self-inflicted catastrophies. Thus far it has always managed to come back and go forward again. Where it has stood still, where it has, perhaps, even fallen behind, is the manifest lack of control over human nature.

Since his early beginnings man has grown in humanity as his brain has expanded—as his forehead has risen above his eyes. Such a conclusion seems irresistible. Placed side by side, the braincasts of the ape-man of Java, the dawnman of Piltdown, the Rhodesian, the Neanderthal, the Predmost and the Modern demonstrate this steady expansion (Fig. 22). The brain area in which the greatest development has occurred is the frontal lobe. Its progressive growth since it made its first appearance gives an ac-

curate impression of the manner in which the brain has responded to the increasing demands made upon it. There are no indications that such demands will decrease in their urgency as time goes on. This fact seems to point in a hopeful direction. It seems equally certain that upon the average only a relatively small fraction of the human brain is at present utilized to the most effective advantages in the interest of humanity. This condition would seem to mean that the power is in our own hands to bring into play more of the brain's potential energy than we have yet developed. In addition to these considerations the human cerebrum may still be looked upon as in its early youth. By most of us it is regarded as a finished product, but its long prehistoric human record as we know it to-day does not support this point of view. This long record makes it appear far more likely that the brain of modern man is only some intermediate stage in the ultimate development of the master organ of life. And furthermore, all the evidence which is available from the long subhuman history of the brain through millions of years of change and modification in the fish, amphibians, reptiles, birds and mammals conveys the strong impression that the evolutionary process has not come to an end with modern man as its culminating phase.

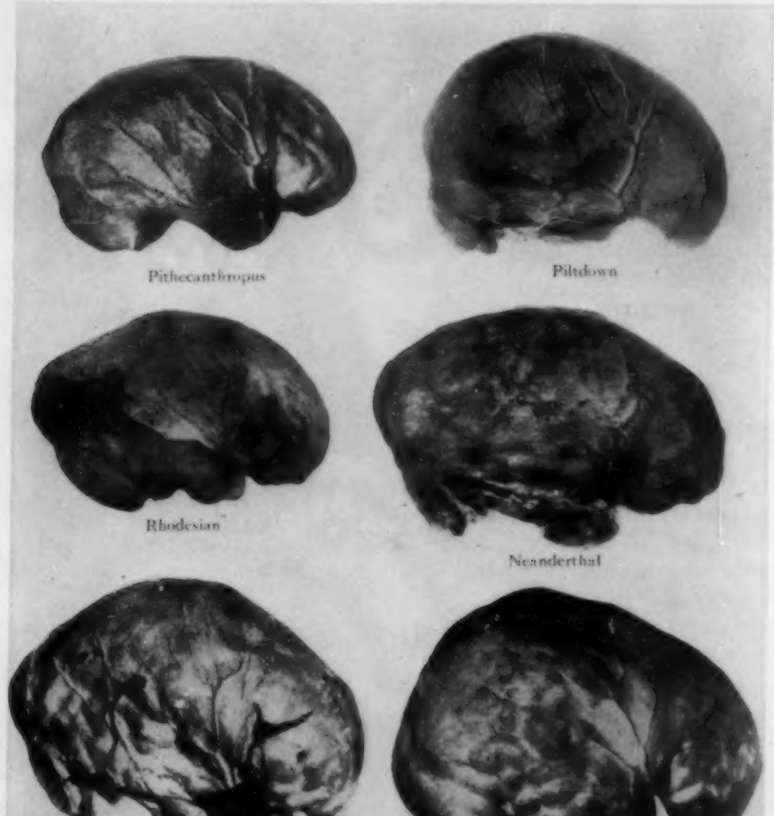


FIG. 22. COMPARISON OF BRAIN CASTS OF PREHISTORIC AND MODERN MAN.

THE CAUSES OF AUTUMN COLORATION

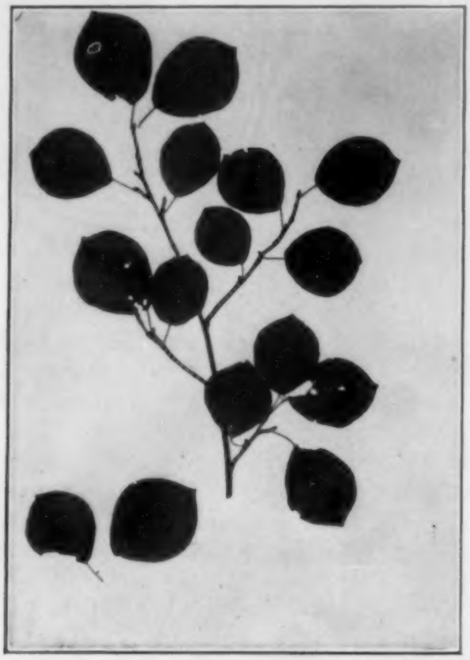
By Professor H. F. ROBERTS

DEPARTMENT OF BOTANY, UNIVERSITY OF MANITOBA

The annual advent of autumn brings before us a splendid pageant, the superb spectacle of the closing of the year, in which the members of the plant world wrap themselves in robes of crimson and gold, as for one last social parade, before retiring into the annual night of winter. The spectacle varies from year to year, varies in length, varies in degree of magnificence. It is as though it were a somewhat human affair. Much has been written regarding the causes of autumn coloration. It was not, however, until the chemistry of the subject had been somewhat fully investigated that it was possible to deal adequately with it. In the first place, let us see just what we are concerned with.

Speaking broadly, the colors of autumn leaves fall into two groups—the reds and the yellows. Without further preliminary, we may say that all the red pigmentation that appears is due to the development in the leaf of what are known as "anthocyanins." The anthocyanins are also found in other parts of the plant than the leaves, and during other seasons than autumn. Generally speaking, anthocyanins are "sun pigments," developing in the presence of sunlight. However, we have intense anthocyanin development in the roots of the beet, and in the outer tissue of the roots of the radish, which, of course, never see sunlight. In high alpine plants, there is a much greater development of anthocyanin in all parts of the plant—stems, leaves and flowers—than in plants inhabiting the lowlands, even in the case of plants of the same species. Our universally common weed, the yarrow (*Achillea millefolium*), which has white flowers in warm lowlands and southerly regions, has red flowers on lofty mountains or in the far north. Even the dandelion has darker flowers under these conditions than with us. A considerable list of plants have been subjected to experiment by European botanists, and the facts as stated have been many times confirmed. As is well known, there are many points of similarity between high alpine vegetation and Arctic vegetation. It was reported by Wulff in 1902, in a special investigation of the flora of the island of Spitzbergen, that the abundant formation of anthocyanin was a distinguishing feature of the vegetation, and so much was this the case that the approach of autumnal coloration was consequently very little marked.

Anthocyanin develops abundantly in the floral organs of many families of plants. Briefly, all red-flowered plants owe their color to the presence of an anthocyanin. It is also noticeable that in plants which bear red flowers, but of which there are also white-flowered varieties, the leaves and stems, and even the seed-coats of the red-flowered varieties, are darker than the similar parts of the white-flowered varieties, owing to the presence of the same anthocyanin which gives the color to the flowers. In sweet peas, for example, the purple- and red-flowered varieties have dark stems and leaves and bear seeds with dark seed-coats. In other words, red- and purple-flowered sweet peas bear commonly dark pigmented seeds, while light- and white-colored varieties bear light-colored seeds. As very common examples of anthocyanin in the petals, we have the ordinary red geranium, the scarlet sage, the red lobelia (*Lobelia cardinalis*), the brilliant flowers of the hyacinth and tulip, the



AMELANCHIER ALNIFOLIA NUTT, SUN-EXPOSED. DEVELOPS ANTHOCYANIN IN THE SUN: VERY LITTLE IN THE SHADE.[1]

common red hollyhocks and innumerable others. Anthocyanin may develop in leafy bracts which surround the inflorescence, as in the brilliant scarlet bracts commonly mistaken for petals, of the familiar poinsettia (*Euphorbia pulcherrima*).

Quite a number of species of trees have produced varieties with red foliage—in other words, varieties with anthocyanin development in the foliage to such an extent as to mask the green chlorophyll. We thus have the purple beech, the purple-leaved variety of the common barberry, the scarlet maple (*Acer Schwedleri*), the purple-leaved plum (*Prunus Pissardi*) and many others. In garden vegetables even, we may have anthocyanin varieties of ordinarily green-leaved species, as in the red cabbage, or in the case of the pericarp of fruits, as in certain red-fruited varieties of plums, in which the anthocyanin pigment is present in both the epicarp and mesocarp of the fleshy edible portion of the fruit. The red banana, which occasionally appears in our fruit stores, is undoubtedly simply another case of anthocyanin development in the epicarp of the fruit. Every summer and fall, we see heaps of anthocyanin fruits in the market, the blueberries, red raspberries, cranberries, high-bush cranberry (*Viburnum opulus*), in the ripe fruits of the gooseberry and many others, and in abundance in the showy but inedible fruits of one of our frequently cultivated shrubs, the Tatarian honeysuckle (*Lonicera Tatarica*) and in the fruits of the "blood orange." The color of red tomato fruits is due to quite a different pigment, lycopin, closely related to caro-

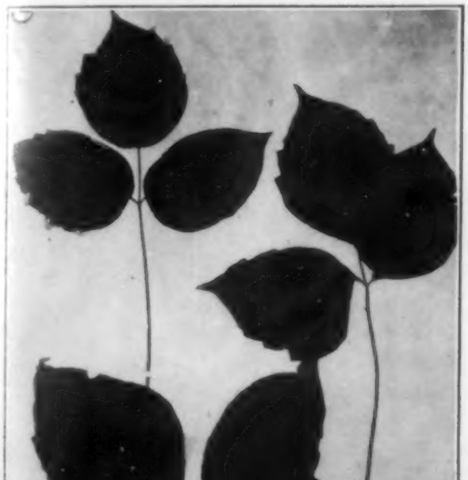
AMELANCHIER ALNIFOLIA NUTT, IN SHADE. VERY LITTLE ANTHOCYANIN.

[1] The illustrations were taken on Wrattan Panchromatic plates. The color-differences come out much more clearly in the prints than it is possible to reproduce here.

tin, one of the carotinoid pigments, and not at all related to the anthocyanins.

The common strawberry, in which the "fruit" is a fleshy swollen stem axis, develops an abundance of anthocyanin. It might be remarked that there are also white or non-anthocyanin forms of the strawberry. Finally, anthocyanin is sometimes developed in the testa or seed-coat of the seeds of many species of plants. This is noticeable in the case of beans, peas, sweet peas, red clover and other leguminous plants, in morning glory, in the ornamental vine *Cobaea scandens*, which has white and purple-flowered varieties, with white and dark seeds, respectively.

This will give us an idea of the wide and indeed almost universal distribution of anthocyanins in the plant world, and we have not even referred to the appearance of anthocyanin pigment in galls and wounded parts of plants, in seedlings in the cool days of early spring, in

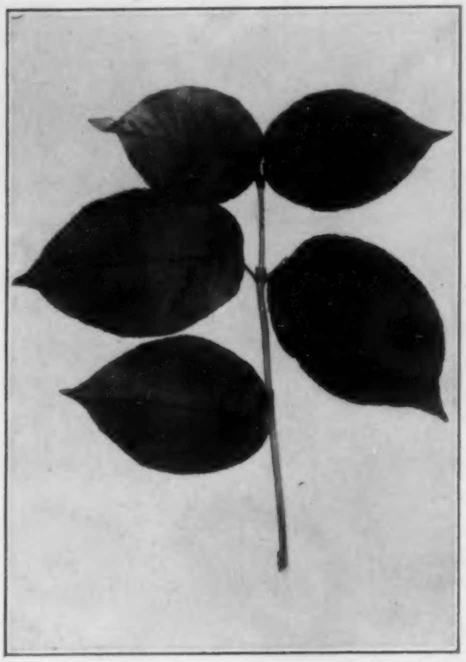


RHUS RADICANS (L.) KUNTZE, SUN-EXPOSED. DEEP ANTHOCYANIN COLOR.

RHUS RADICANS (L.) KUNTZE, IN SHADE. VERY LITTLE ANTHOCYANIN DEVELOPED. PHOTOGRAPH UNSATISFACTORY.

the leaves of many tropical herbs, such as begonias, or in the young leaves and shoots of tropical trees when the spring growth begins in the tropical forests, as described by Professor Keeble, of Oxford University, and others. The latter remarks that the coloration of young foliage at low latitudes "is of such general occurrence, that at the time of leaf renewal, a tropical forest rivals in its tints the autumnal forests of the temperate regions." Johow in 1884, writing of the Lesser Antilles in the West Indies, says, "All at once a red tint, due to the young foliage of the trees, appears in the landscape." The Japanese botanist, Miyoshi, in 1909, observed that leaves of trees in the East Indies, Ceylon and Java redden during the annual dry season, in a manner similar to the reddening of autumnal leaves in the temperate regions.

Now, what is this anthocyanin which



VIBURNUM LENTAGO L. ANTHOCYANIN. DEEP CRIMSON ANTHOCYANIN COLOR.

we find so very widely distributed in the plant kingdom? In the first place, we should say that it is what is known as a "cell sap pigment," *i.e.*, a pigment in solution in the cell sap and not found in plastids. Chlorophyll, xanthophyll, carotin and some other pigments are found in what are known as "chromatophores" —small bodies consisting of specialized masses of protoplasm of characteristic form, which act as holders of the pigment. Anthocyanin is not held in plastid bodies, but is in solution in the cell-sap. If we heat a slice of beet in boiling water, and thereby kill the cells, the red pigment will diffuse from the dead cells out into the water, whereas slices of beet laid in water at ordinary temperature do not allow the anthocyanin pigment to diffuse out, but retain it in the cell sap. The anthocyanins as chemical substances are undoubtedly closely related to what are known as "glucosides." As we have seen, almost all the red, violet and blue pigments present in plants belong to the group of the anthocyanins. The chemical formula for the group may be written $C_3H_6O_5$. All or nearly all anthocyanins are red or purple in acid solution and possess green or blue shades in neutral or alkaline solution. We have said that the anthocyanins are related to the glucosides. Let us refer briefly to the glucosides. They are bodies containing carbon, hydrogen and oxygen, like other carbohydrates, sugar, for example. On treatment with acids or enzymes, a sugar, usually d-glucose, is produced. The glucosides are briefly compounds of d-glucose, $C_6H_{12}O_6$, with various organic compounds. The glucosides are quite commonly found in plants. The oil of bitter almonds, amygdalin, found in bitter almonds, peach and cherry pits, etc., having the chemical formula ($C_{20}H_{27}O_{11}N$), is a common glucoside. Solanin, the poisonous substance in many plants of the potato family, is a complex

RHUS GLABRA L. ANTHOCYANIN. BRILLIANT SCARLET ANTHOCYANIN COLOR.

glucoside, $C_{54}H_{96}O_{18}N_2 \cdot H_2O$. Salicin, $C_{13}H_{18}O_7$, is a glucoside which gives the bitter taste to willow twigs. The dye indigo, originally obtained from the tropical leguminous plant *Indigofera tinctoria*, the indigo plant, is derived from a glucoside known as "indican." The drug digitalis, of great importance in medicine, is derived from four glucosides, of which the most important, digitox, is found in *Digitalis purpurea*, the foxglove, of the family Scrophulariaceae.

An interesting fact was discovered by Combes in 1909, that red autumn leaves of the Boston ivy, *Ampelopsis hederacea*, contain more sugars and glucosides than the green leaves of the same species, and that the amount of anthocyanin varied directly as the sugars and glucosides. Wulff found in Spitzbergen in 1902 that in arctic plants the leaves are very frequently "sugar leaves" and are commonly characterized by the presence of anthocyanin. Experiments by Ewart, on

ACER GINNALA MAXIM. ANTHOCYANIN. BRILLIANT SCARLET ANTHOCYANIN.

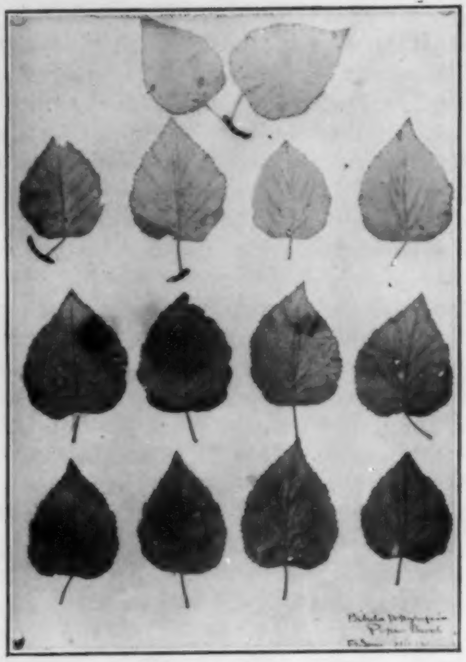
PARTHENOCISSUS QUINQUEFOLIA (L). PLANCK. ANTHOCYANIN. DEEP SCARLET ANTHOCYANIN.

feeding sugar to water plants, show that in addition to sugar, strong light-exposure is required to cause the development of anthocyanin experimentally in these plants. Ewart's experiments were much extended by Overton in 1899, who showed that, in addition to sugar and light, low temperature is an important factor, and that, if the temperature be low but above the freezing point, the formation of the red pigment will be promoted, which accounts for the development of anthocyanin in alpine and arctic plants, and likewise for its development in autumn leaf coloration. The presence of sugar, a low temperature and strong sunlight are required to bring about the reddening of autumn leaves. It can be shown by observation that leaves of species which develop anthocyanin, if exposed to direct sunlight, fail to develop it and show only yellow pigmentation if growing in the shade. A very common instance of this is the case

of the poison ivy, *Rhus radicans*. The same is true of *Viburnum opulus*, the high bush cranberry, and many other species, such as the pin cherry. It is also the case that the leaves of some species which ordinarily develop *only* the yellow pigments, such as the aspen and the Saskatoon berry, will, in intense sunlight, develop a delicate rose tint, showing the slight development of anthocyanin. That sugar is necessary for the development of anthocyanin in autumn

FRAXINUS PENNSYLVANICA MARSH. NON-ANTHOCYANIN. RATHER POOR PHOTOGRAPH. LEAVES ARE DARK YELLOW.

leaves is suggested, aside from the experimental proof that has been cited, by the fact that the leaves of the native oak, *Quercus macrocarpa,* never develop anthocyanin at all on ordinary trees, even in intense sunlight. However, in watershoots or sprouts from the stumps of felled trees, where the presence of stored organic food materials in the medullary rays and other cells of the stump and root enable a quick growth of shoots of un-



BETULA PAPYRIFERA MARSH. NON-ANTHOCYANIN. TOO DARK IN PHOTOGRAPH. LEAVES DISTINCTLY YELLOW.

RUBUS STRIGOSUS MICHX. NON-ANTHOCYANIN. LEAVES BRIGHT YELLOW.

usual length and unusually large leaves to develop, the development of anthocyanin in such leaves is very common and quite striking. Experiments show some variation in respect to the effect of light. Tulip, iris, hyacinth and crocus develop color normally if grown in the dark. Nasturtium and poppy develop color in the dark only if the buds are exposed just before opening. Snapdragon and other plants show less anthocyanin production in the dark, if the buds had not been previously exposed to light. Regarding fruits, it was early noticed by the French botanist, Senebier, that apples do not redden unless exposed directly to light. However, in apples, reddening is not a universal phenomenon; some varieties of apples, such as the Greening, develop no anthocyanin at all. However, in the case of fruits of which the production of anthocyanin is a characteristic feature, as in hawthorn, rose, elderberry (*Sambucus*), it was found that, with partial darkening of the fruits when green, the anthocyanin developed equally well in both the illuminated and darkened parts. Two competent investigators agree that coloration of grapes can take place in the dark.

In general, we may also say that the trees and shrubs of the temperate zone fall, loosely speaking, into classes with regard to the development of the red anthocyanin pigment. There is a tendency among the species of certain natural orders to develop anthocyanin, whereas the genera of other orders are without it. Thus the shrubs and trees of the family of the Rosaceae—species of *Pyrus* (pear), *Prunus* (plum), *Rosa* (rose), *Crataegus* (hawthorn), very readily produce anthocyanin, as do the various species of *Viburnum* of the family Caprifoliaceae. On the other hand, plants of the *Salicaceae* (willows and poplars), *Juglandaceae* (walnuts and hickories), *Betulaceae* (birches and alders), *Fagaceae* (walnut, chestnut and oak) very generally develop no anthocyanin. However, the scarlet oak (*Quercus coccinea*) and the North American hazel (*Corylus americana*) are exceptions. Grapes, hollyhocks, petunias, violets, etc., have one anthocyanin—"delphinidin chloride." Pelargonin, the least oxygenated of any of the anthocyanins, is in many scarlet flowers, such as *Salvia* (scarlet sage), purple and red asters and red geraniums. Cyanidin is the anthocyanin of deep red dahlias, cornflower and poppies, and of the fruits of cherries, cranberries, currants, mountain-ash berries, etc. Peonidin is the anthocyanin of deep red peonies.

Now we must turn from the anthocyanins, which give the autumnal reds, to the yellows of the autumn colors, and we may mention the fact that all shades of intergrading exist between autumn leaf coloration due to anthocyanins alone and coloration due to the yellow pigments alone.

The yellow pigments in the autumn leaf belong to the class of what are known as "plastid" pigments, that is, pigments borne in bodies in the cell known as "plastids." The plastid pigments of the plant cell, in the case of the higher plants, are typically four, two *green* pigments, known as chlorophyll a and chlorophyll b, and two *yellow* or *orange* pigments known as "carotinoids" called xanthophyll and carotin. These four pigments, in the case of the higher land plants, exist in the leaves, on the average, in the following proportions (in percentages of 100).

Pigment	Chemical formula	Percentage in the leaf
1. Chlorophyll a*	$C_{55}H_{72}O_5N_4Mg$.	62 per cent.
2. " b†	$C_{55}H_{70}O_6N_4Mg$.	22 " "
3. Xanthophyll	$C_{40}H_{56}O_2$	9.3 " "
4. Carotin	$C_{40}H_{56}$	5.5 " "

* Chlorophyll *a* in alcohol is bluish-green with deep red fluorescence.

† Chlorophyll *b* in alcohol has a yellowish tinge as compared with a and has a brownish-red fluorescence.

In other words, chlorophyll a is present with chlorophyll b in the proportion of approximately 3:1. Of the two carotinoid pigments, xanthophyll is present in proportion to carotin in the ratio of nearly 2:1. In the fall, as the chlorophylls are decomposed, the carotinoid pigments become visible, often, as has already been said, together with the development of the anthocyanins. The enormous display which the two carotinoid pigments make when they do occur alone, as in the leaves of the elm, the birch and the poplars, is all the more striking when we consider the relatively small percentage by weight in the leaves, which these pigments make. Willstätter and Stoll, the great investigators of the leaf pigments, determined that the total four leaf pigments form 3.25 per cent. of the fresh weight of the leaves, and 8.21 per cent. of their dry weight. The yellow and orange pigments, taken together, form only 0.5 of *one per cent.* of the fresh weight of the leaves and only 1.9 per cent. of their dry weight. In other words, leaving out the anthocyanins, which are responsible for all the red coloration, the great sheet of yellow which spreads over our avenues of elms, and covers the ash trees in the woods, is caused by pigments which form but ½ of one per cent. of the weight of the fresh leaves. How far anthocyanin may go toward producing a color-display may be seen from the humble example of the red cabbage, in which the profound red color is caused by anthocyanin pigment found in but a *single layer of cells* beneath the epidermis of the leaves.

One more addition may possibly be furnished to the yellow pigmentation, viz., the possible occurrence of "flavones," or flavonols, compounds which usually occur in plants in the form of glucosides, *i.e.*, the flavone is combined with a sugar. The flavones themselves give rise to various dyestuffs in plants, such as quercetin, brazilin, to which the well-known haematoxylin dye derived from logwood is closely related. Haematoxylin is one of the most important of dye stuffs. It weights silk to about 200 per cent. of the original weight of the silk, and the volume of the silk is enlarged, so that the fiber has greater increase of wearing surface. However, in the plant, the compounds of flavonol and sugar known as flavone glucosides, are practically colorless. Nevertheless, by chemical action, color may develop. For instance, almost all white flowers turn yellow when exposed to the fumes of ammonia, owing to the formation of a salt of ammonium with the flavones.

The vast majority of yellow to orange-red flowers owe their color, as has been said, to the plastid bodies in the protoplasm of the cells, known as "chromatophores," containing the two carotinoid pigments, xanthophyll and carotin. Very little is known regarding the character and distribution of the carotinoids in most of these cases. In general, however, it may be said that yellows of a primrose or sulfur-yellow color are due to flavones or related pigments dissolved in the cell sap instead of being held in chromatophores. It is interesting to know that xanthophyll, for example, is also found in animal tissues, as in the yellow feathers of many brilliantly plumaged birds, such as the male canary. The color of the yolk of eggs is also due to this autumn leaf-color, xanthophyll. It appears that the autumn carotinoids never equal in quantity those present in midsummer. Tswett, in 1908, has made perhaps the most reliable study that we have at present on which to base a knowledge of the yellow autumn colors of leaves. He studied yellow autumn leaves of nineteen species, and found that the bulk of the yellow pigments before the post-mortal period of the leaf were what he called "autumn xanthophylls." He also found in autumn leaves proof of the presence of colorless substances known

as "chromogens" or "color-formers," which give golden yellow salts with alkalies and which, he held, may at times play a part in autumn coloration.

The flavones, to which reference has just been made, are yellow crystalline substances with high melting-points. They either give a deep yellow or an orange-yellow coloration with alkalies. Their distribution is practically universal in plants. Almost any white flower will turn bright yellow in ammonia vapor, owing to the formation of an ammonium salt. The same yellow reaction takes place in green leaves also, but is masked by the chlorophyll. There is little doubt that the flavones are manufactured in the plants from sugar, although the actual steps are difficult to demonstrate. It has been suggested that the flavones are the sources of the anthocyanins in the plant. Combes obtained anthocyanin experimentally from red autumn leaves of the Virginia creeper, and conversely oxidized the anthocyanin and obtained a flavone.

To summarize, the yellow colors of autumn leaves are due to what are known as the "carotinoid" pigments of plants, xanthophyll and carotin, and principally to the yellow pigment xanthophyll; the red coloration is due to various glucosides known as "anthocyanins," and the varying combinations of different proportions of xanthophyll and carotin, together with the anthocyanins, give the multitude of intergrading shades of orange-yellow, red-and-yellow, red-orange, etc. We should remember that the "carotinoid" pigments are found in the chloroplasts, together with the two green chlorophylls, which give the green color to living leaves, while the anthocyanins are not found in the plastid bodies of the plant cell, but are formed in the cell sap. As the autumn draws on, the leaves become cut off from vital connection with the twigs and branches by a layer of cork, known as an "absciss layer," which forms at the base of the petiole of the leaf and which cuts off the connection between the conducting vessels of the stem and those of the leaf. This brings about gradually the death of the leaf, independently of frost. As the protoplasm of the leaf-cell dies, the plastids, which are protoplasmic bodies, die also, and the green chlorophyll held in them decomposes first, leaving the two carotinoid substances—the xanthophyll and the carotin—which had remained masked by the chlorophyll during the life of the leaf, now fully exposed, and the leaves therefore become yellow. If sugar is present and the leaves are exposed to light, an anthocyanin may be developed, and the leaves may become completely red in color. With less anthocyanin, various combinations of red and yellow develop. Thus we have the autumn pageant of glorious reds and yellows, brightening the landscape of the darkening woods, and, due to the simple fact of the death and decomposition of the green chlorophyll, which throws the hidden yellow pigments into view, supplemented by the gorgeous reds of the anthocyanins produced from the sugars of the leaf. All this occurs when the fall draws on gradually with little frost. An early hard frost destroys the yellow pigments, prevents the development of the red anthocyanins, and the leaves of the forest turn a lifeless brown.

STATE INTERVENTION IN AGRICULTURE[1]

By Dr. J. M. CAIE

Two years ago, Dr. Venn, who presided over this section during the meetings of the association at Norwich, delivered a masterly address on "The Financial and Economic Results of State Control in Agriculture." To-day my subject is "State Intervention in Agriculture," and for any apparent infringement of his copyright I tender him an apology. The reasons for my choice are twofold. In the first place, it is the custom, very rightly, for those who have the honor to be presidents of sections to deal with matters of which they have made a special study or have some first-hand experience. Being a mere administrative official and not a scientific worker, as the term is generally understood, I must, if I am to follow the excellent precedent, restrict myself to the field in which I happen to work.

My second reason is less personal. In the economic and political conditions of the world in recent years the importance of agriculture in the life of the state, not only in this country but elsewhere, has received growing recognition. That recognition may not always have been quite spontaneously accorded; rather indeed it has been extorted by economic and social forces of a most complex and compelling kind. Over-production and under-consumption, of which we have heard so much, have thrust agriculture to the middle of the stage and into the beam of a pale blue limelight. The agriculturist, cast too often for the part of the starving orphan, has raised his voice, now in lamentation, now in vituperation, calling on the state for help or fair play or protection against some industrial ogre or foreign invader. And the state, moved by his "exceeding bitter cry," has played the part sometimes of the fairy godmother, sometimes of the heavy father, and sometimes, so the farmer may say, of the deaf and cunning uncle. But never probably, save in the war years, have the state and the farmers been so closely interested in each other. And that is the second reason for my choice, which I have made in the hope that possibly a general survey of the relation of state and farmer might be of some little value. In attempting that survey, I believe that, despite the title of the paper, I shall trespass little if at all on that part of the subject which was examined so penetratingly and expounded so luminously by Dr. Venn.

One cautionary statement I must make before I go further. When speaking here, I do so entirely as a private individual and not as an official; the department to which I belong is in no way responsible for this address and must not be held as necessarily agreeing with anything it contains.

For purposes of definition, it is desirable to show, as concisely as possible, the part occupied by agriculture in the economic structure of the state. The following tables give the essential facts relating to areas, holdings and populations, the output of food from our farms, and the contribution they make to the total food consumption of the people. As a matter of interest, corresponding figures are given for two other countries, Denmark and Norway, which are more agricultural and less industrial than Great Britain. These tables have been very kindly prepared for me by Mr. W. H. Senior. Most of the data relating to Denmark have been obtained from Pro-

[1] Address of the president of the Section of Agriculture, British Association for the Advancement of Science, Nottingham, 1937.

fessor O. H. Larsen, and those for Norway from Professor Paul Borgedal; I am much indebted to these gentlemen for their kindness and courtesy.

	Great Britain	Denmark	Norway
Number of agricultural holdings.	(Over 1 acre) 455,185 (1935)	(Over 1 ha., *i.e.*, 2.5 acres.) 204,003 (1935).	0.5 ha., *i.e.*, 1.25 acre.) 208,550 (1930).
Total cultivated land, arable and permanent grass.	29,555,271 acres (1935).	7,975,000 acres (1935) (approx.).	2,500,000 acres (1930) (approx.).
Total population.	44,790,485 (1930)	3,550,656 (1930)	2,814,194 (1930)
Number of people per acre of cultivated land.	About 1.5	About 0.45	About 1.1.
Percentage of population in agriculture.	5.7 per cent. (Workers of total occupied population)	29 per cent. (Workers of total occupied population)	30 per cent. (All persons)

The chief facts to note here are the familiar ones, brought out in the last two lines, that in Great Britain the number of persons per acre of cultivated land, 1.5, is relatively high, being three times as many as in Denmark and nearly half as many again as in Norway, while the percentage of the population engaged in British agriculture, about 6 per cent., is very low as compared with 20 or 30 per cent. in the other two countries. Notwithstanding the importance and value of our industrial development, this figure of 6 per cent. has social and other implications which have exercised the minds of many people and need not be elaborated here.

This table shows that, as is again fairly well known, the products of our animal husbandry account for a very large proportion of the output of our land, about 72 per cent. The proportions in Denmark and Norway are even higher, and incidentally it may be remarked that in Scotland the figure stands at about 82 per cent. Our milk, it will be observed, is worth much more than our beef; our eggs are more valuable than the whole of our cereal crops put together, and taken along with poultry are fully equal to our mutton and lamb. This table affords much food for thought to those who are responsible for shaping the agricultural policy of the country. The facts it con-

Agricultural Output, 1935

	Great Britain		Denmark		Norway	
	Pound Million	Per cent.	Pound Million	Per cent.	Pound Million	Per cent.
Meat:						
Beef	39.0	16.2	} 7.4	9.1	1.7	9.1
Veal	3.1	1.3			0.7	3.4
Mutton and lamb	22.2	9.2	0.1	0.1	0.8	4.1
Pork and bacon	20.8	8.7	25.8	31.9	2.1	11.0
Sub-total	85.1	35.4	33.3	41.1	5.3	27.6
Dairy and poultry produce, etc.:						
Milk	53.9	22.4	} 30.2	37.3	7.7	40.3
Butter	5.1	2.1				
Cheese	2.8	1.2				
Cream	0.7	0.3				
Poultry	5.6	2.3	} 6.8	8.4	0.1	0.6
Eggs	17.8	7.4			1.4	7.5
Wool	1.8	0.8	—	—	—	—
Horses	0.1	0.0	1.2	1.5	—	—
Live stock and live-stock products	172.9	71.9	71.5	88.3	14.5	76.0
Crops:						
Cereal, grain and straw	13.3	5.5	5.3	6.5	1.1	5.9
Potatoes	14.9	6.2	} 4.2	5.2	1.1	5.5
Other crops	11.4	4.8			—	—
Fruit, vegetables, flowers and honey	27.9	11.6	—	—	2.4	12.6
Total crops, etc.	67.5	28.1	9.5	11.7	4.6	24.0
Grand total	240.4	100.0	81.0	100.0	19.1	100.0

tains and the agricultural conditions it illustrates are indeed of fundamental importance. These facts result from our soil, our climate and the consequent experience and aptitude of our farmers; they are not entirely unalterable, but any policy of improvement, development or control must primarily be based upon them.

The value of the agricultural output per acre of cultivated land is, in round figures, £8 in Great Britain and Norway, and £11 in Denmark. In contrast to this, the annual output per person in British agriculture is about £200, and in Danish about £150.

SELF-SUFFICIENCY IN REGARD TO IMPORTANT PRODUCTS

		United Kingdom 1935		Denmark 1935		Norway	
		Home Produced	Imported	Home Produced	Imported	Home Produced	Imported
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Beef and veal .		53	47	100	—	100	—
Mutton and lamb		45	55	100	—	100	—
Pork and bacon		50	50	100	—	100	—
Poultry	(G.B.)	78	22	100	—	100	—
Eggs		66	34				
Milk (liquid)..		100	—				
Cheese		30	70	100	—	100	—
Butter		10	90				
Wheat		26	74	7	93	33	67
Barley		46	54	95	5		
Oats		91	9	—	—	—	—
Potatoes		96	4	100	—	100	—

N.B.—Estimates for United Kingdom and Denmark based on quantities, those for Norway on values.

The figures in this third table need little comment and are in a sense a corollary to those in the two previous tables. As regards animal products, the two Scandinavian countries are self-supporting, whereas we produce only about, very roughly, half our requirements of the various kinds of meat, nearly four fifths of our poultry and two thirds of our eggs. We produce all the liquid milk we consume, but only 30 per cent. of our cheese and 10 per cent. of our butter. Of wheat we import about three fourths of our annual ration and of barley fully half, but we grow over nine tenths of our oats and nearly all the potatoes we eat.

So much for agriculture as a producer. What about agriculture as a buyer of the products of other industries? Only a rough and possibly unreliable estimate can be given. According to the farm accounts obtained for 245 Scottish farms, of different kinds and in different districts, for the years 1934–35, the estimated expenditure on building materials, implements and machinery, electricity, fuel, chemicals, fertilizers, etc., amounted to from 14*s*. to 20*s*. per acre of cultivated land. Admittedly this is a small sample on which to base a generalization, but, taking it for what it is worth, it would represent a gross total of from twenty to thirty million pounds for the whole country. The corresponding figures per acre are for Denmark 26*s*. (based on 810 farm accounts for 1935–36), and for Norway from 12*s*. to 21*s*.

It may be noted that no allowance is made for the personal purchases of the agricultural population, which presumably would be made, more or less, no matter what the employment of the people might be. The figures represent the purchases of the agricultural industry as such and show to what extent it is the customer of other industries.

The word "intervention" is sometimes used as being equivalent to control. In this paper it has a wider meaning and is intended to cover the various ways in which the action of the state may impinge on agriculture—the "impact" of the state on agriculture, to borrow the word employed by Sir Josiah Stamp in his presidential address to the association last year. Intervention, according to this definition, falls broadly into three categories: (1) Control, *i.e.*, statutory compulsion, enforced by penalties; (2) the statutory provision of means by which agriculturists may take voluntary

action to do certain things and, in the event of such action, to compel a minority to conform to the wishes of a majority; (3) the giving of direct or indirect assistance, financial, advisory, protective, etc.

Let us first consider control. A complete stranger visiting these islands might receive an impression, perhaps from an agricultural newspaper, or a farmer's meeting, that the agriculturists were oppressed by the rules and regulations of a government that joyed in tyranny, aided by a horde of official tormentors who not only battened on the sufferers but were often accused of being the real inventors of the legislative boots and thumb-screws. The depth and permanence of that impression would depend in the first place on where the stranger came from. If he came from certain European states, the impression might be fleeting; comparing conditions here with those to which he had been accustomed, he might soon say, "Here is peace: here indeed is freedom." And if he looked a little under the surface and studied the relation of state and people in this democratic country, he would discover that a government, no matter how inspired by good intentions and a large majority, could rarely if ever pass a law that was unacceptable to the general community, agricultural or other, or, if it succeeded in doing so, would find it very hard to administer it effectively. To legislate in advance of public opinion is no easy matter. Those who have to do with the formulation of legislative proposals, subsequently to be embodied in parliamentary bills, know that an Act of Parliament does not emerge suddenly, fully armed from the head of Jove. Usually it is only after prolonged discussion and consultation with organizations and individuals that a bill takes shape and gets into sufficient training, so to speak, to run the gauntlet of parliamentary criticism. It is true that a government, having to weigh as best it can the conflicting claims and interests of different industries and sections of the population, may not always meet the wishes of agriculture; but on examination it will generally be found that while it may withhold desired benefits, it seldom if ever attempts to impose an agricultural law to which there is wide and strong objection throughout the industry. The contribution of the civil servant, the so-called bureaucrat, to the legislative process may be one of labor and anxiety, but to call him the real villain of the piece is to flatter him and to ignore the fundamental and very real principle of ministerial responsibility. The British civil servant is truly a servant, informing and advising so far as he reasonably may, but always obeying loyally the government of the day, no matter what its color or its political philosophy may be. And, if I may say so, British ministers, of whatever party, do not fail to accord to the Civil Service a corresponding loyalty and that protection from any party criticism without which the service's impartiality and devotion to duty could not be maintained. The system is the product of a long evolutionary process; it may have defects, but it is at any rate the fruit of the political genius of the British nation. This, however, is something of a digression.

If our foreign visitor were historically minded, he might be interested to look into the past to see how present measures of control compare with some of those to which agriculture was subjected in former days. I have no time in this paper, nor have I the qualifications, to accompany him in any comprehensive study of the subject. One can but glance at a few of the more noticeable instances, in some cases forming precedents or foundations for later legislation. In his "English Farming Past and Present" Lord Ernle says that, "In the early stages of history, the law itself was powerless to protect

individual independence or to safeguard individual rights. Agriculture, like other industries, was therefore organized on principles of graduated dependence and collective responsibility. Medieval manors in fact resembled trade guilds. . . ."

These continued until the local and gradual break-up of the manorial organization of agricultural labor was accelerated by the Black Death (1348–49). Labor became so scarce that panic wages were asked and paid until in 1349 by Royal Proclamation all men and women "bond or free," unless tilling their own land or engaged in merchandise or in some other craft, were compelled to work on the land, where they lived at the rate of wages current in 1346. Here, nearly 600 years ago, was wages regulation of a pretty drastic kind, but it was a maximum that was fixed, not a minimum. Later on, in 1563, we find another notable effort to control the labor market in the Statute of Apprentices, which enacted, *inter alia*, that all persons between 12 and 60, not exempted by the statute, could be compelled to labor in husbandry and that masters unduly dismissing servants were fined and that servants unduly leaving masters were imprisoned. It also stated hours of labor and provided for the fixing of wages by Justices of the Peace.

The story of land enclosure is well known and need only be mentioned as an illustration of state intervention, operating first in one direction and afterwards in another. In the sixteenth century, land enclosure, involving "the break-up of medieval agrarian partnerships and a substitution of private enterprise for the collective efforts of village associations," was opposed and partly arrested by legislation; in the eighteenth century it received from Parliament encouragement and support. Many individuals suffered, but the ultimate benefits to agricultural production and to the state as a whole can not be denied. It is interesting to note that in 1589, to relieve the laborers who lost their livelihood through the enclosure of land for pastoral purposes, it was enacted that not more than one family was to occupy each cottage, and to each cottage 4 acres of land were to be attached. The recent movement to provide allotments or small pieces of land for unemployed industrial workers seems almost like a faint echo of that distant law.

As an example of compulsion indirectly benefiting agriculture, one may cite the law passed early in the seventeenth century making it a penal offence for any person over the age of six not to wear on Sundays and holidays a cap made of English cloth. Later, in 1666, the law did not stop short even at the gates of the churchyard, for it required that the dead should be buried in shrouds of home-grown wool. In passing, it may be noted that about the same time the Government, "for the sake of multiplying seamen," had ordained fast-days on which only fish was to be eaten. With precedents of that sort before us, we are almost tempted to long for an act making the consumption of oatmeal, milk and herrings obligatory, and the possession of a tin-opener a criminal offence; it would solve several current problems of Scottish agriculture and fisheries.

Legislation of another kind prevailed throughout the eighteenth century, when home production was encouraged by the placing of a duty on the importation of foreign corn and the payment of a bounty on exported corn, combined, however, with frequent prohibitions of exports. Similar laws were enacted to encourage the raising of cattle, and importations from Ireland were prohibited. But legislation, says Lord Ernle, did not raise prices; it only succeeded in maintaining them. Increased production at home counteracted the effect which limitation of imports was designed to produce. It is unnecessary here to retell the story of the corn laws and of their repeal or to touch on more recent fiscal controversies.

The earlier instances of state intervention that I have cited were all English, but the Scottish parliament also provides us with some interesting examples. With regard to labor, the extinction of serfdom having been considered productive of indolence, a statute of 1424 required cottage holders to perform a certain amount of labor on the land, a provision for which we have had an English parallel. At almost the same date, 1426, we find Parliament taking partial control of cropping. To secure a greater variety of crop than the oats and bere which were chiefly cultivated, it was enacted that every man tilling with a plough of eight oxen should sow every year at least a firlot of wheat, half a firlot of peas and forty beans, "under the payn of ten shillings." At a much later date, 1703, a curious act relating to cultivation was passed, forbidding any butcher to have more than one acre of land for grazing unless it be tilled annually, under penalty of £100 Scots for each offence, loss of the cattle found grazing and loss of the freedom of the burgh. Public health and amenity were not overlooked, for to improve the aspect of the country, check malaria and provide shelter, all freeholders were required (1457) to plant on their land trees, hedges and broom. Nearly two hundred and fifty years later (1695) an Act for the preservation of meadow lands and pasturages near sandhills forbids the pulling up of bent, juniper and broom.

The necessity of keeping down weeds was recognized in the statute which required the cleansing of land from "guld," *i.e.*, marigold. The act, with a touch of humor now sadly lacking in modern statutes, sets forth that any one who planted "guld" deserved punishment as amply as if he had led an army against the king and barons.

Pig-feeding was discouraged. No burgess could permit swine to remain in the fields without a keeper, and they had to be kept out of plantations and hunting ground, while it was decreed by Parliament that the owner of a hog which made a hole in a meadow or open place should be compelled to fill the hole with grains of wheat.

Security of tenure is a subject of which we still hear. In the middle of the fifteenth century (1449) there was passed what might almost be called the first of the Agricultural Holdings Acts. It provided that "for the safetie and favour of the puir papil that labouris the grunde, that thay and all utheris sall remaine with their tackes unto the ischew of their terms, quhais hands that ever thay landis cum to." In other words, a change of ownership of the lands did not involve the dispossession of the sitting tenants. Our present law restricting the period for "making muirburn," *i.e.*, heather burning, goes back, with some difference of the dates, to at least 1400.

Storage of grain, a measure now advocated by some for purposes of defence, was not considered desirable in the fifteenth and sixteenth centuries, for in 1449 it was enacted that "to prevent dearth," no old stacks of corn were to be kept in the yard after Christmas; in 1452 the date was extended to the end of May; and in 1563 to the 10th of July.

These few examples of how in the past the state has laid its hand, sometimes heavily, sometimes helpfully, on agriculture are obviously very far from exhaustive and are not intended in any way to constitute a historic survey. They have been selected almost at random, to show that intervention—call it interference if you will—however much we may think we suffer from it to-day, is no new thing. You will observe that the intervention was almost all of the compulsory kind, the single exception among the instances quoted being the Scottish Act conferring a degree of security of tenure. My second category is not represented and there is no bestowal of direct benefits, such as subsidies, etc.

Having glanced at some precedents, let us consider the present state of affairs. We are all, of course, subject to state control of various kinds; we must educate our children, pay income-tax, drive our cars carefully, refrain from buying or selling certain goods after certain hours, and so on. Some people think we have far too much of such control, others find their yearnings still unsatisfied, and are eager to kiss, or to see others kissing, almost any new rod. There are, indeed, probably few of us who could not mention some objectionable thing that other people ought not to be allowed to do. But here we are considering not the common burdens that have been laid upon all citizens, but only those special ones that have been imposed upon the agriculturist as such. I am not going to trouble you with a catalogue of Acts of Parliament, nor need I refer to the various compulsive or restrictive measures of war-time. It will be sufficient to mention some of the existing laws in my first category that come most readily to mind.

The farmer is bound to furnish to the government annual statistical returns of his crops and live stock. For many years the returns were made voluntarily, but since 1925 they have been compulsory. The filling up of forms is one of life's minor worries, but no one could say that the compilation of accurate agricultural statistics is not essential for the proper understanding of many of the major agricultural questions with which the government and the farmers themselves have to deal.

The Contagious Diseases of Animals Acts, administered for the whole of Great Britain by the Ministry of Agriculture and Fisheries, may at times interfere seriously with the activities of the farmer as a stock-owner, but without them he would undoubtedly be exposed to vastly greater and possibly catastrophic losses. Similarly, the Destructive Insects and Pests Acts may occasionally hamper him as a crop grower, but on the other hand they afford him protection with which he would not willingly dispense. These two laws are in fact more protective than restrictive, and I have never heard any one suggest that they should be repealed.

As a breeder of horses and cattle, the farmer must conform to the requirements of the Horse Breeding Act and the Licensing of Bulls Act, which are designed to prevent the use of inferior sires. Here again agricultural opinion is, in general, entirely on the side of the law; representations have, in fact, been received from responsible quarters that the principle should be extended to pig-breeding.

A statutory system of prescribing and enforcing the payment of minimum wages to agricultural workers has been operative in England since 1924, and Parliament has recently passed an act introducing a similar system into Scotland, where at the time of the passing of the English act, and for several years after, the workers themselves, as well as the farmers, were opposed to having such legislation. Here perhaps we come to a subject not quite free from controversy. But if it be accepted that without such legislation there is a danger that the pay of the worker might fall below the amount necessary to maintain him and his family in a reasonable degree of comfort, there are few who would deny its justice. Criticism of the law has been based not, I think, on this ground, but rather on the ground that certain other steps should be taken to enable the farmer, in his economic difficulties of recent years, to pay a satisfactory wage. The criticism, so to speak, has been consequential rather than direct; there has been little opposition to the fundamental principle embodied in the acts.

The Corn Production Act is remembered with mingled feelings. One solitary vestige of it remains in operation, the section requiring the destruction of

certain specified weeds. As these are weeds which, if unchecked, may spread far and wide, there need be little sympathy with the delinquent who permits them to grow, to the detriment of his fellow-farmers.

Under the Milk and Dairies Acts, the dairy farmer, in the interests of public health, has to conform to certain standards of cleanliness, accommodation, equipment, etc.

Certain restrictions, not very onerous, are laid on farmers by such acts as the Animal Anesthetics Act, the Dangerous Drugs Act, the law relating to Heather Burning in Scotland, the Slaughter of Animals Act, and some others which may occur to you.

Whether the state presses more or less heavily on agriculture than on other businesses, *e.g.*, shipping, mining, manufacture, shops, railways, etc., I am not in a position to estimate; but later in this paper I shall venture on the opinion that the farmer is perhaps fortunate in that the hand of the law does not hold him in a tighter grasp than it does at present.

I come now to my second category of state intervention: that in which the state does not at first hand compel or prohibit, but gives farmers the opportunity to organize themselves for certain purposes and, should the necessary majority of producers decide to avail themselves of the opportunity, empowers them to secure conformity by the minority and to impose penalties on recalcitrant or erring individuals. The Agricultural Marketing Acts are the only laws that come strictly within this definition, although the Agricultural Produce (Grading and Marking) Act is similar in that the adoption of the National Mark under it is permissive, but when it is adopted it conveys a statutory guarantee of quality, with penalties for misuse. As you know, the Marketing Acts are a recent institution in this country. Hitherto, agricultural cooperation for the marketing of agricultural products had been on an entirely voluntary basis, with the advantages and disadvantages inherent in such a system: on the one hand, complete freedom of the individual, and on the other the danger that the desires of a majority might in practice be frustrated by a minority who, for various reasons—personal gain, shortsightedness, secretiveness, love of individual independence—were unwilling to observe the rules and limitations necessary to secure successful collective action. But under the Marketing Acts, cooperation can be fortified with some very effective artillery. Fundamentally, however, the principle is still voluntary and the system democratic. Unless the required majority of the producers of a certain commodity vote in favor of the marketing scheme submitted to them at a poll, the government has no power to impose a scheme upon them. In Scotland, for example, two raspberry marketing schemes have been rejected at the poll and there the matter ended. And should a scheme be adopted and approved by Parliament, it is administered by a board elected by the registered producers themselves.

The need for improved marketing methods in this country is widely, if not universally, admitted; the economic dangers and disadvantages to the farmers of the indiscriminate sale of their goods in haphazard quantities and of irregular quality by hosts of unrelated producers have been only too apparent in the past; and the weakness of purely voluntary cooperation as a remedy has been illustrated more than once. (The comparative failure of the Scottish Milk Agency scheme may be cited as an instance.) In view of all this, the difficulties and controversies to which the Marketing Acts and their derived schemes have given rise may be a matter for some surprise, but only, I think, to those not familiar with all the facts. One fact is the strong individualism of the British farmer, begot-

ten of tradition, experience and his whole way of life. Sometimes, in the modern world, individualism may be a handicap; but the modern world too can show us many instances in which its absence is even more to be deplored. In this country most of us still believe that, in the words of John Barbour, "Freedom is ane noble thing." We must, however, retain our sense of perspective, and it is possible to exaggerate the degree of subservience to which farmers are subjected by a scheme which a majority of them was free to accept or reject and which, when accepted, is administered by their own representatives. Another and an important fact is that the marketing schemes are of a novel and necessarily complicated kind. Experience has to be gained, experiments have to be made, the engine has to be run in, mistakes in driving, sometimes serious mistakes, are inevitable for a time. Patience and tolerance are required. It is better surely to adjust the bearings and tighten loose nuts than to throw the spanner into the works and wreck the whole machine. For even the critic must admit that the acts and the schemes are at least earnest attempts to remedy serious defects in one important side of British farming.

The subject is being treated in a separate paper this morning, and I do not propose to discuss it in any further detail. But I will conclude my reference to it by quoting the opinion of one authority who has written: "The Marketing Acts are the equipment for a great experiment in the possibility of farmers organizing their industry themselves, with due regard to the interests of the consumers. If the experiment succeeds, it may postpone indefinitely such drastic changes in the structure of agriculture as those which are taking place in Soviet Russia. If it fails, not less but more control will be inevitable." How many of you will agree with that view I do not know.

Having considered briefly the methods by which the state helps the farmer by laying restrictions on him for his good and by handing him the keys with which to open, if he will, the palace called Organized Marketing, where the enchanted princess, disguised as the British housewife, awaits him, let us now, in the third place, glance for a moment at the other ways, some of them quite direct, in which he is aided and supported. Fortunately, it has been unnecessary for me to seek out all the facts from the numerous and sometimes rather elusive official publications and records in which they are contained, for that difficult task was most ably performed two years ago by Dr. Venn, to whose address I refer you. At the levels then current, the gross total of financial assistance afforded to agriculture, including forestry, and allowing for local taxation reliefs, amounted to upwards of thirty-three and a half million pounds, from which he deducted ten and a quarter millions representing the debit caused by the action of the Wages Committees, thus bringing out a net gain of about twenty-three and a half millions. Some adjustment of these figures is required at the present date. Owing to the rise in the price of wheat, the wheat subsidy, which as you know is not a direct Treasury grant but is obtained from the consumers of flour, is at present negligible. On the other hand, the cattle subsidy now stands at five millions instead of three and a third, and sums amounting to a maximum annual total of £3,490,000 have lately been promised in respect of oats and barley, lime and basic slag, land drainage and the reduction of live-stock diseases. In his balance sheet, Dr. Venn, no doubt wisely, made no allowance for the option afforded to the farmer of being assessed for income tax on his rent instead of on his actual profits, should these prove to be the greater. What that special concession is worth, it is impossible to estimate, but with any improvement

in the financial position of the industry its value progressively increases.

The items in the balance sheet, apart from the recent additions which I have mentioned, are, as you may remember, wheat, beet, meat, milk, land settlement and allotments, afforestation, local taxation reliefs and administrative and development services. This last is a comprehensive item embracing many and varied matters such as live-stock improvement, land drainage, etc., and including the subjects which are of special interest to many members of this section, education and research. For the financial year 1912–13, the state grants for these subjects amounted to £65,750 in England and Wales, and £34,889 in Scotland, a total for Great Britain of £100,639, whereas in 1936 the corresponding figures were £628,570 in England and Wales, and £136,769 in Scotland, a total of £765,-339.

These are large and striking increases, but it must be remembered that for many years our standard of expenditure on these services was much lower than that in several other countries, so that if we were to attain, as we have done, fairly adequate recognition of their importance within a reasonable time, a steep financial ascent was inevitable. In view of the interest in the subject, it is tempting to ascertain whether this growing outlay has been reflected in an increased yield of agricultural products. The question, however, is not an easy one to answer, since many factors are at work, and it is difficult to ascribe an increase to any particular one. The output of live-stock products, for example, must depend very largely on the prices of imported feeding stuffs. Possibly the least fallacious measure to apply is the average yield per acre of our principal crops, though here again the problem is not simple. For instance, if the total acreage of a crop falls, the average yield per acre tends to rise, since it is from the least suitable land that the crop will be withdrawn; conversely, an extended acreage will probably mean a somewhat smaller average production. It is subject to this and other qualifications that the following table should be taken as providing any indication of the effects of our education and research. The figures are for 35 years from 1900 onward and are given as quinquennial averages, so as to smooth out to some extent annual fluctuations due to weather conditions, etc.

In Great Britain as a whole, wheat, the acreage of which has fallen since the war years, shows no significant increase, oats are up by four or five bushels and potatoes by something like half a ton, but rotation hay has made no advance in spite of a reduced acreage. The results are not

Period	Wheat	Oats	Potatoes	Rot. Hay
1900–04				
Acres	1,645,774	3,094,642	569,399	2,331,575
Yield	29.83 bushels	39.24 bushels	5.65 tons	29.50 cwt.
1905–09				
Acres	1,725,616	3,061,529	572,176	2,179,882
Yield	33.28 bushels	40.56 bushels	6.20 tons	30.23 cwt.
1910–14				
Acres	1,852,994	2,964,502	585,842	2,041,321
Yield	31.28 bushels	38.50 bushels	6.29 tons	28.76 cwt.
1915–19				
Acres	2,227,592	3,428,908	650,973	1,989,169
Yield	30.56 bushels	39.18 bushels	6.19 tons	29.10 cwt.
1920–24				
Acres	1,879,088	3,107,942	666,289	2,124,750
Yield	31.94 bushels	38.30 bushels	6.18 tons	28.92 cwt.
1925–29				
Acres	1,546,255	2,725,711	646,886	2,000,654
Yield	32.30 bushels	43.38 bushels	6.48 tons	28.38 cwt.
1930–34				
Acres	1,516,509	2,428,413	614,942	1,884,938
Yield	32.20 bushels	43.56 bushels	6.56 tons	28.58 cwt.

spectacular, but the economic difficulties of many farmers, in the later periods, must be kept in mind. Any variations are, however, in the right direction, and striking changes in averages for the whole country could hardly be expected. A general rise in national production is bound to be a slow movement. But there are doubtless considerable numbers of the more progressive farmers who, by availing themselves of the aid offered by the scientist, have obtained increases much in excess of any shown in the table. It has to be remembered, too, that even where yields have not increased, costs of production may have been substantially reduced.

There are some other branches of state intervention which, notwithstanding their importance, it must suffice just to mention: protection of the farmer by means of import tariffs and quotas, designed to raise or maintain the prices of his products; the Agricultural Holdings Acts, controlling the relationship of landlords and tenants; land settlement legislation, which enables new holdings to be established on land which, under certain conditions, may be compulsorily acquired for the purpose.

In the course of an hour's address it is not possible to do more than take a hasty glance at this large subject, with its many interesting ramifications, any one of which might well have a whole volume to itself. But inadequate as the survey has been, there are one or two deductions that may perhaps be drawn from it.

Comparison of an agricultural country like Denmark with an industrial country such as ours must not be carried too far. Marketing and other organization, opportunities of alternative employment, standards of living, necessarily differ in the two countries. But allowing for all this, the statistical tables quoted in the earlier part of the paper suggest that British agriculture at present falls short of producing as much home-grown food as is possible and desirable for the nutrition of the people and also of affording employment on the land to as many persons as is reasonably practicable. The need of higher nutritive standards for a number of our population and the importance, in attaining these standards, of larger supplies of certain foods, in the production and marketing of which our farmers have some natural advantages, are now generally recognized. This recognition is tending to encourage the development of certain branches of our agriculture and it is to be hoped that the process will be a progressive one. Some authorities seem to consider that the sole impetus required to accelerate the process is to increase the purchasing power of the lower-paid groups of the population. That is certainly a factor of much importance, but there may be need too for education in the principles of nutrition, not only among these groups, but among some others as well. This aspect of the matter will no doubt be kept in mind should it be thought advisable to devise schemes for securing the desired object.

When speaking of the greater employment of the people on the land, one is apt to be reminded at once, and quite properly, that, thanks to the activities of the scientist and the engineer, the output per unit of agricultural labor is steadily rising. This is a tendency that can be neither ignored nor retarded. Increased production, therefore, may not necessarily cause increased employment. But, on the other hand, it is probably true that it will be long ere, in this country, the large-scale mechanized farm, the ideal of the economist, is the general and normal agricultural unit. And, given reasonable prospects of even moderate commercial success, there are many for whom rural life holds a fascination and independence denied to the townsman and the factory worker. For agriculture, as has been said, notably by Professor W. G. S. Adams, in his paper read to this section at Aberdeen, is not only a living, but a way of life. To live in that way, they are

willing to risk the financial vicissitudes of the farmer or even to undertake the arduous labors of the small-holder. Cynics may call it sentiment; it is none the less a fact. But the question is by no means entirely one of settling people in new holdings; at present it is indeed rather one of making up leeway both in land and in the people employed on it. Since before the war, two million acres have gone out of arable cultivation. The reclamation of waste lands in England, the repopulating of our Scottish glens are perhaps less immediately possible, but is it too much to hope that at least a good part of these two million acres might be recovered? Were it solely a matter of farming economics, the shrinkage of our cropping area and extension of our grass-lands might perhaps be regarded with equanimity, especially if the grass were of reasonably good quality. But wider issues are involved; the effects on employment and food production can not be left out of account.

In the second place, when one compares the amount of control to which agriculture is subjected by the state and the amount of benefits, direct and indirect, which it receives, one can not fail to notice some disparity between the two. The state is paying the piper fairly substantial sums, but while it exercises a little restraint over some of his actions, its only method of calling the tune is to offer special rewards for certain specified melodies. Some people may say that the payments should be larger, or different in form or in distribution; others perhaps may think that with so much foreign music available, it does not greatly matter what our piper plays. But at any rate the fact is that the selection of the tunes is ultimately determined only by individual choice. And one can hardly help asking, somewhat anxiously, whether, if the system of payments, in their various forms, is to be continued or extended, the freedom and independence of the piper can be maintained. To drop the metaphor, if it be the policy of the state to preserve and support the farmer, at considerable cost, is he to cultivate and crop his land, to produce meat or milk or other products, as he thinks best, without any dictation as to methods, quantity or quality? I would emphasize that the question is not whether the farmer should be supported and protected, but only whether there is a possibility that, sooner or later, certain consequences may follow from that policy. It is true, as I have said earlier, that it is difficult for a government to pass and to administer an unwelcome law; but if government aid were made conditional on government control, the farmer, however distasteful he found it, might be induced to swallow the pill for the sake of the gilding.

It may be argued that the state, in return for its expenditure, whether in the form of direct payments or of artificially raised prices, is entitled to demand not only certain goods, but a certain standard of performance, a view that found expression in Part IV of the Corn Production Act, which gave "Power to enforce proper cultivation." In response to that argument, it may be claimed that if the farmer is to be bound to produce commodities of a kind, quality and amount determined according to the kind and area of his land, he should be insured against any loss incurred in the process. And that leads to the further question: if he is to be insured against loss, is he to be left free to make unlimited profits, should his efforts prove successful? It is easy to follow out this line of thought and to see complete control, including rents as well as wages, following in due course, and, indeed, the ultimate incorporation of every agriculturist in the Civil Service! *Timeo Danaos et dona ferentes!* Possibly this is all merely academic speculation, but given the premise of state support, the subsequent reasoning does not seem to be entirely falla-

cious. Whether the conclusion, if it were ever reached, would be a desirable one, is a matter for individual opinion.

Thirdly, it may be noted that, while some of the state benefits, *e.g.*, rating relief, the fruits of education and research, etc., are bestowed upon all, certain others, *e.g.*, the wheat and beet subsidies, are, owing to natural conditions, not universally available. This is a thorny subject—although not quite so prickly as it was a few months ago—about which some of us have heard a good deal in the last year or two. The state is, of course, entitled to pay for those commodities the production of which it wishes to maintain or increase, or to come to the rescue of those whom it deems most needful or deserving of succor. If, for instance, a "nutrition" policy required an increase of, say, meat or milk or fresh vegetables, or if the agriculture of one part of the country were, for some reason, in special jeopardy, the disbursement of funds for such purposes would appear to be perfectly legitimate. But if it were a permanent policy for the state to support British agriculture in general, it might perhaps be desirable to survey the whole industry, its place in the social and economic structure of the country, its present and potential capacity to meet the food requirements of the people and its relation to international trade. These subjects are no doubt being studied now, but it can hardly be claimed that the study is complete. Perhaps it never can be completed, for many of the factors are far from static. But if a comprehensive, reliable and possibly continuous survey could be made, it might form the basis on which state aid might be allocated equitably, from time to time, to those branches of the industry which it was desired, in the public interest, to encourage and in proportions according to their needs. But on this assumption, the shadow of state control still lurks darkly in the background.

This leads one, lastly, to consider whether in state aid, with its attendant shadow, lies the only hope for British agriculture. The question is one of paramount importance and of formidable difficulty, on which any one should hesitate to dogmatize. But for some at any rate there would be comfort in the belief, if they could hold it, that our farmers, given a fair share of our home markets, could once more struggle through their difficulties and maintain their position by their own initiative, energy and resource. For many of them, times have been hard, but many too are riding out the storm with courage and success. Observation, supported by careful economic investigation, shows that the personal factor is still one of enormous importance. Within one parish, even on neighboring farms, great disparity in farming practice and results may be found. The man of enterprise and adaptability, the man who is eager to acquire new information, to test new methods in the light of his practical experience and to apply his mind to the business management of his undertaking, he is the man who is least clamant for state subvention to help him in balancing his accounts. Education and research, both scientific and economic, have yet many gifts in store, gifts the acceptance of which carries no penalties. If they be accepted willingly and applied diligently, is it not possible that the general standard of our farming might be raised to a level at which it would be beyond the reach of any, save the very heaviest, waves of depression? If not, there seems to be at least a risk that our farming, no longer the free industry that we know and respect, may become a mere hanger-on of the state, dependent on its bounty and subject to its commands. Economic independence is worth a struggle, for with it may go a higher kind of freedom that is worth the hardest fight of which man is capable.

TALAMANCA

By RALPH E. DANFORTH
WEST BOYLSTON, MASS.

"The Cordillera of Talamanca, the most extensive mountain chain and the one containing the loftiest peaks. This area is difficult of access and has hardly been touched by the botanist, although it is likely to prove the most remunerative part of the Republic." So wrote an eminent scientist and traveler, Dr. Paul C. Standley, in the annual report of the Smithsonian Institution of 1924.

Talamanca became a charmed word to me and the difficult and little-known southeastern half of Costa Rica, containing the highest mountains in Central America, became a mecca for a future pilgrimage. It contains a vast virgin forest, as wild as that encountered by the first white settlers in America. Its trees average about one hundred and twenty feet in height, many of them one hundred and fifty and two hundred feet, with clear stems and the lower limbs eighty or ninety feet up. Mountain torrents dash down its steeps, overarched by the straining limbs, yet often too wide for these to conceal. From the air above, these broader rivers are seen to lace the vast, rugged expanse of green with lines of frosted silver and add to the strange bird songs the roar of cataracts and the song of the incessant battle between torrents and bowlders and ledges. But why leave the comforts of a New England home to do a bit of research in a region destitute of the basic comforts of civilization? Partly perhaps the blood of pioneer ancestors, partly the jungle pictures in the geography book of schooldays, the fascinating monkeys swinging on lianas, the pictures of tropical birds on strange trees of the jungle. All through life the wilderness trees and their inhabitants have lured me in many lands. Talamanca's turn came. I reached the civilized belt which stretches across the middle of Costa Rica, with its comfortable cities dotting the railroad and excellent highways. I read of its cowboy and cattle country to the northwest, but of the southeast the majority of Costa Ricans themselves know little. The few frontiersmen who live in the little clearings in the forest seldom come to town and when there are quiet and unobtrusive. The townsfolk told me they knew little of the Talamanca Mountains or what one might expect who penetrated them. They had heard of poisonous snakes, "*león*" and "*tigre*," as they call their cougar and jaguar. They knew there were some Indians, though fewer than before. One could not enter by wheeled vehicles. One might go on foot or mountain pony, carrying blankets and food, or now he can fly by small local planes to a few of the larger clearings which depend upon these planes for all transportation which can not take many days of rough travel over narrow, mountain trails.

Flying thus southeasterly, from ten degrees north of the equator at San José to nine and a fraction degrees at San Isidro del General, I reached the base of Chirripó Grande, the highest group of peaks in the Talamancas. The highest peak is 12,586 feet above sea-level. Looking down from above on range after range of mountains clad in unbroken forest, one is amazed at the vigor and vitality of the trees. Each looks so perfectly healthy, although never dusted or sprayed for insect pests. Shades of green differ with the species. Here a

palm or two appear among the broad-leaved trees, or a few tree-ferns vary the foliage. What new species might abound or what rare finds were awaiting among those millions of energetic trees? The biological balance in the jungle is so perfect that despite fierce competition between living organisms the myriads of forms which fill it seem vigorous, superbly healthy and, to me, they appear peacefully happy. Large flocks of parrots flew together in a wheeling, exuberant flight, noisy and unmistakably joyous. Unless one mistook their every act and sound they were glad, sporting together in the air as they flew from one food tree to another. Whatever perils the jungle had for them, these did not dampen their spirits, and having seen the joy of living which these free and far-flying birds show almost constantly, I felt I could henceforth view captive parrots only with pity, as they live lives so diametrically opposite their life in the wild. Strangely colored toucans with huge bills sang creaking songs which carried far across country and might mislead one into thinking that ox-carts with ungreased axles abounded in the wilderness, when in truth the few carts had to be assembled or made in the clearing. Birds large and small, plain and gay, abound, more, it seemed to me, than in the West Indies. Lizards were fewer, and mosquitoes almost non-existent. Fleas bothered only in the village and might easily be avoided in a camp in the edge of the forest if dogs and people infested with them were barred. In the forest the air was of the sweetest. No pests bothered, unless one stirred up a colony of stinging ants inhabiting some hollow stem, though these were easily removed. Snakes and beasts there were, but these were as loath to meet man as any one might wish.

Dr. Alexander F. Skutch, a young American scientist, is spending many months in the region studying habits of living birds while he collects and preserves plant specimens for museums to make his living. He lives in a camp by himself, hiring two boys to assist in house and field. He lived "three hours on foot" from where I stopped, but he was many miles above his camp when I sought and found him. On the mountain-side I visited with him two hours as he worked. Rain is frequent and the plant-press must be protected as one works. In my own collecting the numerous rivers afforded chances to pick flowering specimens from trees which ordinarily hold these treasures ninety feet or so in air. The smaller trees are more easily collected. Skutch was collecting seven series of everything from ferns up. He surely earns his living, but what a rare environment to live and work in!

My own time in the actual forest was limited to three weeks. Every moment must count, so I camped on the edge of the clearing, where I suffered from fleas nightly, and bought food ready-cooked and saturated with grease, sooner than take time to establish myself in the actual woods and cook the food myself to my own taste. But I resolved hereafter to take time to do it the right way. Fortunately I endured the fleas and the grease with no permanent detriment to health, and so had every hour of daylight for study of the forest. It was August, 1936, therefore in the rainy season, and only a fraction of the species were in bloom. As I was out primarily for specimens of trees actually in flower my scope was limited. The forty odd species I did find in bloom were of great interest. They represented many genera and families and included two species new to science. *Cordia chirripensis* Standl. and *Rollinia Danforthii* Standl., also one South American species, *Wikstroemia fruticosa* Schrad., which had not previously been found in Central America,

and one rarity, ***Stryphnodendron excelsum*** Harms., which had not been found since the type collection in June, 1903.

Everything in that vast virgin forest excited curiosity; the species not in bloom seemed almost endless; birds abounded both in number of individuals and number of species. Pests and diseases of the trees seemed under excellent natural control. Indian graves, betokening a more numerous population in the past, were being searched for gold and other valuables.

Rushing mountain rivers abounded everywhere, and it was along their courses that I was most successful in reaching flowering branches which ordinarily would be high above reach. This entailed much wading and swimming and climbing over slippery rocks. The water from higher up the mountains was always cold. Rain also drenched me nearly every afternoon. Life was strenuous but thrilling.

The present state of civilization in that unique and youthful pioneer clearing known as San Isidro del General is worthy of a few comments. There was one Romanist church with a young German padre. There was no inn or lodging room in the village. Two huts offered hot meals, such as they were, for sale. What few dwellings there were were grouped around a flat open field called hopefully the Plaza. One hut housed the post office and government radio station. The settlement was served by three competing local airplane companies. Pan American planes flew high overhead, traversing the length of Central America and Mexico, but of course made no stop at small places. There were several small stores, most of them run by Chinamen. All mail and practically all goods to or from San José were carried by airplane. When it came time for me to leave the forest I wanted to mail a number of heavy packages to West Boylston, Massachusetts, and took them to the San Isidro del General post office without really high hopes of success. But the postmaster said I could mail them to the States, but he had no tariff but would radio at once for rates. These came back from San José without delay, and he soon showed me them neatly typewritten. But alas, he had no scales for packages, so we took them to the agent of one of the aviation companies and he weighed them, for cheerful cooperation in a pioneer clearing is essential. The local post office kept no postage stamps, but took the cash, and by some system the proper stamps were put on in San José, always on the bottom of the package or back of the envelope. The business of the clearing was far larger than the few houses would warrant, for it was the center for isolated individual clearings for many miles around.

There was much excitement over the prospect of the Pan American highway passing through. They knew it would develop the region, yet feared the consequences in case of war.

Weddings occurred at 6 A.M. in the church, the ceremony being followed by a wedding breakfast in a neighboring house. I was invited to one such breakfast, which consisted of sandwiches, home-made cake and coffee. The usual meals consist of home-grown rice, black or red beans, potatoes, which are also grown in the mountains; tortillas made from corn meal, a few fruits and a few other vegetables and a little bread are used. Agua dulce is often substituted for coffee. This is crude sugar in hot water. The lumber is hand-sawn and used while still green. House wrens much like ours at home nest in the thatched roofs. The many birds of the forest always added to the pleasure of tree study.

If the big highway does go through the

region, it will hasten the ruin of that magnificent forest. Even now it is a shame to see it cut and burned to rid the ground of it, ground much of which should never be cleared. The whole Talamanca range of mountains would make a magnificent national park, which, when better known, would draw people from all around the world. Its flora and fauna are unique in many respects, and mingled with its many endemic species are also forms from South America, from Mexico, and in winter from much further north. But if the entire range would be too much to ask for, at least that Chirripó Grande massif, which towers above all the rest of the range, should become at once a permanent virgin and wild-life refuge with complete protection from fire and axe.

Scientifically managed forests for timber production should be provided over increasing areas. Wild forests, in which nature is left entirely free to conserve or to reconstruct primeval or virgin forest conditions, will always be needed in generous amounts for study purposes and for instruction and edification of the people. Such wild forests should exist in every distinctively typical forest region, and should contain as many native species and as many endemic species of tree and shrub as possible. The educational value of such wild forest consists not only in the opportunity to study the various species at all seasons in their natural habitat, but also in showing how nature deals with the infinite number of biological problems arising in various ecological and different climatic environments. There is also the esthetic value of such wild areas, appealing to an ever increasing number of people in all parts of the world, and there is the artistic side to be treasured.

Virgin forests could and should be permanently conserved in all far-away regions. They might with benefit be reconstructed, in limited amount, close to our large cities and in all more densely populated areas. They have their peculiar values, as have also our more familiar city and state parks. It would do the public good to visit areas where they know there can be absolutely no tampering with nature, no destruction, no "improving" and no exploitation, only a few narrow trails to admit observers.

FROM FANCIES TO FACTS IN DIAGNOSTIC MEDICINE

By Dr. J. HEYWARD GIBBES
COLUMBIA, S. C.

ARCHEOLOGY, anthropology and the study of primitive peoples show conclusively that medicine, meaning thereby the healing art in some form or other, is as old as man—that the dawn of his consciousness brought with it a striving to recover from disease, to heal himself when injured and to diminish the pangs of pain. Surgical instruments have been found by the archeologist, in their particular human settings, from the Stone Ages through the Bronze and Iron Ages, and anthropologists have discovered human bones in these respective ages which show that primitive man knew how to reduce and fix fractures so as to prevent shortening and to permit of union. Primitive peoples of to-day, some of whom are living under conditions of Stone Age Man, such as the Dayaks of Borneo, some of the Malay tribes, and others, together with what we know of the medical customs of the American Indian, have allowed us to see in actual operation the thought and practice of early man in his efforts to get relief when sick. B. M. Randolph has said that there is "a deep-lying instinct in human nature that relief from suffering is an obtainable goal," and the history of man's striving to satisfy this instinct is the history of medicine.

The sensation of pain, the capacity to suffer and the desire for relief naturally made themselves felt in man before his mental processes, based on experience and observation, had become sufficiently organized to permit of an understanding by him of the causes that produced his misfortunes. In the beginning he probably suffered and vaguely hoped for some surcease. Aches and pains, chills and fever, stiffness of joints, shortness of breath, the pangs of angina, the fits of epilepsy, the gnawing of ulcers, the depressions and excitements of mental aberrations and innumerable other agonies seized him or crept upon him without his knowing how or why. But as he suffered he thought, groping for explanations of the evils that beset him, seeking for intelligent direction in deliverance from them, and instinctively knowing that he must find the causes of his troubles if he were to cure them or avoid them in the future. Out of this thinking came his theories of disease, working hypotheses of cause and effect, that would serve as a foundation on which to build measures for restoration of health in mind and body.

Specialized thinking on such subjects was assumed at an early date by the recognized mental leaders of the tribe, the priests, the chiefs or others who, through special qualifications, were set apart from the rank and file. And thus we have the groundwork for the study of medicine, the observation of disease, the ceaseless theorizing about it, and the endless effort to explain it, understand it and relieve it.

What we have come to call theory and practice have gone hand in hand, and when the one has been empirical and unintelligent, the other has taken on like qualities. Theory, in medicine, has come to mean knowledge: where it is short of this, practice must remain uncertain and insecure. It is my purpose to rapidly trace the steps by which medicine, in its diagnostic aspects, has progressed from

primitive conceptions to its present stage of relative mechanical accuracy.

Early man was surrounded with mystery. He explained himself and the world about him in terms of mystery. He found his destiny moulded by gods and devils, demons and spirits. His diseases came from devils and demons—his cures came from driving out the malignant influences that pervaded him. To meet such problems, his medicine men dressed in weird costumes, dealt in charms and incantations, danced mystic dances and performed esoteric rites for his relief.

A tangible evidence of the demonology of primitive medicine is found in neolithic skulls, recovered from many parts of the world, that show numerous trephine openings, small disks of bone having been removed so that the demons causing the disease might escape. This interpretation is warranted by observations of similar practices by barbarous peoples of our time.

Our knowledge of Egyptian medicine comes largely from six or seven papyri dealing specifically with this subject. The Ebers papyrus, dating from about 1500 B.C., indicates a persistence of demonology as a cause of disease, with incantations as measures of relief, but gives a remarkable list of pharmaceuticals, ointments, inhalations, enemeta, poultices, drugs, such as opium, castor oil and squills, and shows that more or less skilled operations on the eye were undertaken. While we are struck with some of the empirical successes of this period, we realize that mystery and magic remained the foundation of the thought of Egyptian medicine, and that they were groping without understanding.

Astrology and divination were the bases of the theory and practice of medicine in Babylonia and Assyria. The reading of horoscopes in the heavens and the divination of destinies as disclosed by inspection of the organs of animals, especially the liver, indicated the mystic formula that was to be used in exorcising the demon from the afflicted person. Hepatoscopy, the reading of the liver, was developed into a complicated rite, elaborate charts of the liver were prepared, and an accurate reading of the signs disclosed by the organ were confidently expected to give useful information as to the cause and cure of disease.

It remained for the Greeks to banish demons from the realm of medicine, not by making holes in the skull, but by enlightening the mind from within by inquisitive thinking and by "lifting the veil of nature," as Dr. Osler has expressed it, so that we might observe and study her features. Among the factors that led to the development of the vigor of the Greek intellect, Gomperz says, "there was the religion of Hellas, which afforded complete satisfaction to the requirements of sentiment, and yet left the intelligence free to perform its destructive work." The Greek intelligence quickly destroyed the demons of disease. Under the Greek influence, medicine, along with the study of nature in general, gradually became emancipated from the shackles which had bound it to the religious thought and customs of all preceding peoples.

Abstract thinking and speculative inquiry, guided by the principles of logic, were the chief weapons employed by the Greeks in their study of nature and in their development of science, and, until observation and inductive methods were developed, they elaborated theories of humors and numbers in their relation to disease that appear to us weird and fanciful. Some of them, however, spurred by a restless curiosity, resorted to dissection, made accurate and enduring observations, and laid the foundation of a knowledge of anatomy, from which root spring all the branches of medical science. Notable among these were Alcmaeon, a member of the Crotonian school, who

first recognized the brain as the organ of mind, Democritus, who developed an atomic theory, and Diogenes. Hippocrates codified, as it were, the medical concepts of the period, showed the value of painstaking clinical observations, and voiced many sapient aphorisms that we like to repeat to this day. He it was that said, "experience is fallacious and judgement difficult," and "the remedy amuses the patient while Nature cures the disease." The greatest observer and systematizer of them all was Aristotle, who came close, indeed, to an unravelling of many of nature's secrets. As regards medicine he says:

> But health and disease also claim the attention of the scientist, and not merely of the physician, in so far as an account of their causes is concerned. The extent to which these two differ and investigate diverse provinces must not escape us, since facts show that their inquiries are, at least to a certain extent conterminus. For physicians of culture and refinement make some mention of natural science, and claim to derive their principles from it, while the most accomplished investigators into nature generally push their studies so far as to conclude with an account of medical principles.

The philosophical vigor of the Greeks must forever remain a source of unending charm and inspiration to any one whose soul has beauty in it and whose mind is spurred by curiosity, even though they have served to show us that abstract thought and simple observation will not wring nature's answers from her—that questions must be asked through orderly and controlled experiments, a method that must be added to theirs from the full fruition of an inquiring intelligence.

It is not until we reach the Renaissance that we find the newly awakened intelligence of man, rediscovering the wisdom of the Greeks and adding a new *modus operandi* to his way of thinking, effectively investigating natural phenomena, acquiring information hitherto unknown and slowly laying by in enduring form a mass of knowledge to be built on and added to as his experience grew and his methods of investigation improved. As Aristotle suggested, the growth of natural science caused medicine to grow with it, and medicine rapidly developed a science of its own.

It is axiomatic that anatomy is the foundation of intelligent medicine. The structure of the body as a whole, and of its parts and organs separately, must be known in detail before the diseases and disorders to which they are subject can be comprehended. As we look back over the vista of human knowledge, we see outstanding in the realm of anatomy the colossal figure of one man, Andreas Vesalius (1514–1564), who, through genius, industry and daring, exposed the fallacies of the past and established truths for the future. Anatomical knowledge of a sort had preceded him, sporadic observations here and there concerning the structure of the human body, mixed with information gained from dissection of the lower animals, and the whole joined together in a maze of theories, doctrines and generalizations that were fixed and unchanging under the dominance of authoritarianism. Galen had written the medical bible, his word was the law, and to question it was to be guilty of medical heresy. As Vesalius dissected his human subjects, he read his Galen, and he was amazed to find the discrepancies between the texts and the facts. It grips the imagination to picture the conflict that arose within him, the growing feeling that truth and authority were at odds. And, then, the light—the realization that Galen had not dissected the body of man, but had described the anatomy of lower animals. This brought comfort to the mind of Vesalius, and stimulated him to his task, though it did not lighten his difficulties in persuading others that Galen had been wrong. In 1543, at the age of twenty-

eight, Vesalius published his book, "De humani fabrica," containing 663 pages in folio and over 300 illustrations, the first complete text-book of human anatomy. From this substantial beginning the knowledge of gross anatomy has been completed to infinite detail.

In the same year that Vesalius died, 1564, Galileo was born, destined to discover the compound microscope, through which agency gross anatomy was to be supplemented and rendered complete by microscopic anatomy of organs and tissues. Antony van Leeuwenhoeck (1632–1723) was a pioneer in this field. Grinding his own lenses and making his own microscopes, he visualized bacteria, observed the cross striation in muscle fibers and described the bone corpuscles. But Marcello Malpighi (1628–1694) was the first to systematically study microscopic anatomy. He was to this branch of knowledge what Vesalius had been to gross anatomy. The two of them pointed the way that has led to a rounded knowledge of the detailed structure of the human body.

To pragmatic medicine a knowledge of function is of equal importance with that of structure. On these two pillars, anatomy and physiology, rests the intelligent foundation of medicine as we know it to-day. William Harvey (1578–1657) is commonly looked upon as the father of physiology. The ingenious experiments which he employed in demonstrating the circulation of the blood may be said to have established a methodology which was sound in principle and which showed the way for studies of bodily function. However, it was Albrecht von Haller (1708–1777), the versatile Swiss genius, poet, anatomist, botanist, biologist and physician, who first made physiological investigations on a broad and systematic basis, published the first text-book on the subject, awakened the curiosity of other students and stimulated others to investigations in this field. From this beginning, physiology has kept pace with anatomy in that intensive, critical and analytical studies have been applied to the body as a whole, to its parts separately and collectively and to its minutest components in an effort to find out their manner of working. Much real information has been gained, absorbing and astounding facts, which has permitted medicine to advance in much of its endeavor from speculation to certainty. But the story is far from completely told. The complications that are furnished by chemistry, physics and mechanics, associated with the intangible thing that we call life, leaves us with problems of infinite variety and ever widening complexity. It is probable that in this field medical science has more ground to till than in any of the others that it has thus far cultivated.

The knowledge of normal structure and of normal function are stepping stones in the evolution of modern medicine to an understanding of modifications of structure and function that are produced by disease processes. As far back as the fourth century B.C., Erasistratus had observed and described changes in organs that were found after death, for example, hardening of the liver in association with dropsy, and isolated observations of a similar nature are recorded by others of the ancients. In the latter part of the fifteenth century, Antonio Benivieni left a record of 111 observations of clinical cases with an effort to correlate the clinical and post-mortem findings in many of them. By the seventeenth century the practice of making post-mortem examinations had been greatly extended. But out of it came no systematic effort to relate the changes caused by disease to the signs and symptoms of the disease that were observed prior to death. Giovanni Battista Morgagni (1682–1771) came to a full realization that disease results in physical changes in the organs and tis-

sues of the body, that these changes result in perversions of function and that they together result in the pictures that are seen in clinical medicine. Dr. Osler, in his "Evolution of Modern Medicine," cites a classical passage from Morgagni's writings:

> A lady, forty-two years of age, who for a long time had been a valetudinarian, and within the same period, on using pretty quick exercise of body, she was subject to attacks of violent anguish in the upper part of the chest on the left side, accompanied with difficulty of breathing, and numbness of the left arm; but these paroxysms soon subsided when she ceased from exertion. In these circumstances, but with cheerfulness of mind, she undertook a journey from Venice, purposing to travel along the continent, when she was seized with a paroxysm, and died on the spot. I examined the body on the following day. . . . The aorta was considerably dilated at its curvature; and, in places, through its whole tract, the inner surface was unequal and ossified. These appearances were propagated into the arteria innominata. The aortic valves were indurated.

Commenting on these pathological changes, Morgagni says, "The delay of the blood in the aorta, in the heart, in the pulmonary vessels, and in the vena cava, would occasion the symptoms of which the woman complained during life; namely, the violent uneasiness, the difficulty of breathing, and the numbness of the arm." Here we have a clinical description of angina pectoris, a study of the physical changes in the organs that accompany the disease and a retrospective explanation of the symptoms that were caused by these changes.

Morgagni furnished the impetus for the study of pathology, the science of morbid structure resulting from disease. It was a far cry from demons to tissue changes, but Morgagni was pushing aside philosophical concepts of disease and forging the tools by which speculation and theory were to be supplanted by hard facts and physical changes. The era of modern medicine may be said to have been born with Morgagni. From this beginning we have now progressed to a more or less detailed knowledge of the physical changes that are produced in the organs and tissue of the body by practically all the diseases from which man suffers.

Rudolph Virchow (1821–1902) realized early in his career that pathological anatomy was not expressive of a full understanding of disease processes and that it failed to offer an altogether useful basis for the most intelligent treatment of sick people. He saw the need for determining the alterations in function of organs and tissue that was brought about by the physical changes that disease produced in them. In the introductory number of the "Archiv für pathologische Anatomie und Physiologie und für klinische Medizin," he said:

> The standpoint we propose to adopt, and which is clearly manifested in this first issue, is simply that of natural science. Practical medicine as applied theoretical medicine, and theoretical medicine as an embodiment of pathological physiology, are the ideals toward which we shall strive so far as lies within the scope of our powers. Pathological anatomy and clinical work, although we fully recognize their justification and independence, are both mainly regarded as the sources of new problems whose answers must be supplied by pathological physiology. Since, however, these problems must for the most part be formulated by means of a laborious and comprehensive study of detailed phenomena in the sick and upon the post-mortem table, we maintain that a precise and purposive development of anatomical and clinical experiences is the first and most important requisite of the day. Through an empiricism of this sort there will gradually be brought into being a genuine theory of medicine, a pathological physiology.

Virchow's ideal has approached reality. Physiological principles and techniques have been applied to the clinic, specific means of investigating the function of different organs have been devised, and these measures now afford some of the most exact and valuable diagnostic criteria that clinical medicine has at its disposal.

Speculation as to the cause of disease, as is true of abstract thinking in general, gave little in the way of tangible and worth-while results. Until the middle of the last century we knew little more of the causes of infectious diseases than did the Greeks or the Egyptians before them. In 1857 Louis Pasteur published his paper on "Lactic Acid Fermentation," and, shortly thereafter, a paper on "Alcoholic Fermentation" in which he concluded that such fermentation is "correlative to a phenomenon of life." The turn of Fortune's wheel directed the genius of this man from the field of chemistry to that of microscopic biology, and his work laid the foundation on which has been built our knowledge of the living causes of infectious diseases. From a study of the diseases of wine, he turned to the study of diseases of the silkworm, from that to the diseases of animals, and finally to an investigation of rabies in man. He demonstrated the presence of viable agents in all these studies, and pointed out methods for controlling them. In addition, he arrived at an understanding of the mechanism of defense in the host which permitted of recovery from infection. On the work of Pasteur has been built the two great related sciences of bacteriology and immunity, the science of the cause of infectious diseases and the science of tissue reactions that arise in response to such infections.

The unremitting search for bacteria and other living parasites, as the cause of acute diseases in man, that owes its impetus to Pasteur's work and thought, has resulted in the demonstration of something more than twenty specific bacteria that produce characteristic disease pictures, has led to an understanding of other infectious diseases for which the specific bacteria have not been identified, and has been indirectly responsible for the discovery of filterable viruses, fungi, protozoan and metazoan parasites as the cause of human disease.

I feel safe in saying that Pasteur's influence on medicine, as we know it to-day, has been even broader than stated above. The emphasis that was laid by him on the cause of disease led to the thinking in terms of causes for all diseases, and with him dawned the era of etiological or causative medicine. From the pragmatic standpoint, the control or cure of a disease can be attained only when its cause, at least in a general sense, is known. To-day, as physicians, we think in terms of causes, our medical nosology is built around them, and the success or failure of our efforts is in large part dependent upon the accuracy or inaccuracy of our conception of causes. Aside from diseases that are due to living organisms, we recognize physical causes of disease, chemical causes that are clear and definite, deficiencies in diet that produce specific changes, diseases of metabolism that are traceable to assignable causes within the body, and tissue changes that arise from excessive demands on certain parts of the body or that come as "slow gradations of decay" as age passes into senility.

In the clinic, we have learned to identify these living causes of disease. Bacteria are grown in cultures from the body's fluids or tissues or are visualized in smears by staining methods, and their by-products are demonstrated by biological reactions. The different forms of parasites are directly seen or their presence determined by the finding of their eggs. Here we have diagnostic procedures of the most direct and positive nature.

The study of the individual sick of disease is, of course, the immediate concern of diagnostic medicine. The problem here is divided into two broad categories, the discovery of the disease from which the patient is suffering and a determination of the manner in which the body of the patient has been altered in structure and function by the disease. It is neces-

sary that we know disease, and it is necessary that we have at our disposal means for exploring the body. The evolution of methods, looking to these ends, is a fascinating story of ingenuity and accomplishment.

Thomas Sydenham (1624–1689), spoken of as the English Hippocrates, stated that "all disease could be described as natural history." With this in mind, he set out to make such descriptions, observing and recording cases from the appearance of the first symptoms to the disappearance of the last. Sigerist has said of Sydenham:

> Like Hippocrates his general outlook upon illness was that it was a natural healing process. Nevertheless there lay a whole world between the two. The decisive difference between them becomes plain in respect of their divergent outlook upon illness as soon as they quit the general. Hippocrates recognized only disease, not diseases. He knew only sick individuals, only cases of illness. The patient and his malady were for him inseparably connected as a unique happening, one which would never recur. But what Sydenham saw above all in the patient, what he wrenched forth to contemplate, was the typical, the pathological process which he had observed in others before and expected to see in others again. In every patient there appeared a specific kind of illness. For him maladies were entities, and his outlook upon illness was, therefore, ontological. Hippocrates wrote the histories of sick persons, but Sydenham wrote the history of diseases.

From this we have come to the modern clinical record, a careful compilation of racial, familial, occupational, climatic and other influences leading to disease, a description of the symptoms that accompany the disease, a detailed observation of the course of events that go with the disease, and facts concerning its duration and mode of termination. This clinical record, brought more and more to completeness as time and experience have permitted, has written the natural history of disease so that generalization has been possible, and many diseases are now recognized by the course of events that are produced by them. And the clinical record of a current case is now an important diagnostic adjunct, permitting the disease, as it were, to gradually identify itself by the trail that it leaves on the printed page.

When it comes to the study of the sick person, the physician can gain much information by the unaided use of his five senses, taste, touch, vision, hearing and smelling, but an enlargement of the field of these senses has been brought about by ingenious aids that magnify and penetrate so that things can be seen, heard and measured which were formerly inaccessible to such investigation. The developments in this line, the mechanical, physical, biological and chemical aids that clinical medicine has brought into use, have given real meaning to the term diagnosis, literally, to distinguish, to discern or to know apart. Let us look at some of these aids.

The study of the pulse in disease has gone on since early times. Herophilus, who gained fame as a physician, philosopher and teacher at Alexandria in about 300 B.C., held that the pulse was to be considered on the basis of rhythm, as in music, and carried his thesis to such lengths that only those trained in music could interpret the pulse as expounded by him. Galen (131–201) wrote seventeen chapters on the pulse, and no one was much the wiser for it. It is said that Galileo used his pulse to time the swinging of a pendulum and that Kepler timed his astronomical observations by the same means. Galileo's friend, Sanctorius, reversed the process, and used a pendulum to time his pulse. He devised an instrument, which he called the pulsilogium, consisting simply of a weight at the end of a thread which swung with increasing or decreasing frequency as the cord was shortened or lengthened, and by this means he was able to measure and record the rate of the pulse in terms of cord length. In the latter part of the

seventeenth century, Sir John Floyer, of Staffordshire, made a so-called physician's watch, which ran for just one minute, none of the watches of that date having second hands on them. In 1855 Karl Vierordt introduced the graphic method of investigating the pulse, and this was shortly followed by Marey's sphygmograph. This has evolved into the so-called polygraph, an instrument which records simultaneously the pulse at the apex of the heart, in one of the larger peripheral arteries and in the great veins of the neck. From such tracings valuable diagnostic information can be gained.

Sanctorius, likewise, developed the first clinical thermometer, if the crude glass tube used by him to measure the amount of warm air that the patient expired can be recognized as such. George Martine (1702–41), of Scotland, revived Sanctorius' ideas, and James Currie made practical use of the thermometer in the treatment of fevers with cold water. Carl August Wunderlich (1815—1877), of Leipzig, was the first to make systematic thermometric observations at the bedside, to keep temperature charts and to determine finally the types of febrile reactions in different diseases. Modifications of the clinical thermometer are now available for different types of work, and such delicate instruments as the dermatherm have been devised so that minor changes in the surface temperature of the skin can be determined.

Inspection or looking, palpation or feeling, percussion or the listening to notes that are produced by tapping, and auscultation or the listening to sounds that are generated within the body are the four pillars of physical diagnosis. Dr. Osler has said that many more mistakes in diagnosis are made from not looking than from not knowing, and certain it is that simply by looking we can gain much diagnostic information. By palpation, the art of feeling with the hands, much can be found out about disease processes on the surface of the body and to a less extent inside of it, notably by feeling through the soft abdominal walls and inside of the various body orifices. But until the eighteenth century the bony wall of the chest effectively shielded the organs inside of it from the curious eyes, ears and fingers of the physician.

In the middle of the eighteenth century, Leopold Auenbrugger (1722–1809), a Viennese physician, remembering how his father, an inn-keeper, determined the level of wine in casks by tapping on them, applied the principle of tapping or percussion to the examination of the chest. Through painstaking experiment and collection of data he gave to medicine the art of percussion. By this simple means we have learned how to map out the size and position of the heart, to discover the presence of tumors in the chest and to detect the replacement of air-containing lung tissue by the products of inflammation or fluid.

Supplementing the discovery of Auenbrugger was that of Laennec (1781–1826), the French student of disease who was impressed with the importance of listening to sounds that were generated by diseased hearts and lungs. In passing through the court-yard of the Louvre, he observed a group of children who were engaged in signalling to each other through a hollow beam. Hurrying to the hospital he made a cylinder of a piece of paper, applied one end to the chest of a patient and the other end to his ear. New fields were opened to his hearing, the stethoscope was born, and the real art of auscultation was introduced into medicine.

This quadrad of physical diagnosis, inspection, palpation, percussion and auscultation was firmly established by the early years of the nineteenth century; it remains the basis for the clinical examination of patients, and a physician's

excellence may in large part be judged to-day by the skill and judgment that he displays in using it. Supplementary aids have come in large numbers, chemical, physical and biological procedures that test it and elaborate it, none to supplant it, all adding glamor and strength to this natural equipment of the physician in his diagnostic efforts.

The application of chemistry to diagnostic medicine has brought new significance to the study of the urine. We need no longer say with Webster in the "Duchess of Malfi," "the urine is the physician's whore, for she cozens him"; nor need we send such messages as the page took to Falstaff, when, in reply to the question, "Sirrah, you giant, what says the doctor to my water?", the page replies, "He said, sir, the water itself was a good healthy water; but for the party that owed it, he might have more diseases than he knew of." Likewise, chemical studies of the blood, the saliva, the gastric juice, of the body fluids and effluvia in general and of the respired air have brought us methods of precision and of inestimable value as diagnostic procedures.

Physics has found its place over a wide range in clinical medicine. The sphygmomanometer, an instrument for measuring the pressure of the blood within the arteries, owes its origin to the work of Stephen Hales (1677–1761) who, in 1733, described his experiments in determining the arterial blood pressure in horses by the simple expedient of fastening a long glass tube inside of an artery and reading directly the height of the column of blood. The column of blood has been reduced to a column of mercury, which is connected by rubber tubing to a distensible sack, which, after being applied to an arm or a leg, is inflated until the flow of blood in the main artery underlying it is shut off. The pressure required to do this is thereby registered by the column of mercury in a millimeter tube. Light, either direct or reflected or in the form of electrically lighted instruments, has opened the portals of the body to direct inspection, deep down into their recesses. Electricity has given us the x-ray as a means of penetrating vision, galvanic and faradic currents for the study of nerves and muscles, and such instruments as the electrocardiograph for the study of action currents that are generated by the contraction of the heart muscle. Polariscopes, spectroscopes and colorimeters now play an integral part in diagnostic efforts. The microscope has a multitude of uses in clinical medicine and is essential in the proper examination of every patient.

Of course, we have done nothing more than touch the high spots in showing the application of physics to medicine, but it is probably enough to indicate the avidity with which medicine avails itself of every opportunity for supplanting inexact observations and opinions with physically exact measurements and records.

Studies in the fields of serology and immunology have brought us some of our most important diagnostic aids. Paul Ehrlich (1854–1915), through the elaboration of differential stains, recognized the varieties of white blood cells that normally occur in the circulating blood, and showed how these normal values were modified, in quality and in quantity, by bacterial invasions of different kinds and by certain chemical poisons. His studies led him to a theoretical explanation of immunity, or the mechanism by which the body develops a resistance to the disease processes which attack it. Emil Behring (1854–1917), working at the same time as Ehrlich, specifically studied the antitoxins that are to be found in the blood serum in response to the introduction of toxins of bacterial origin. Means have

been found for identifying these products of reaction in the blood serum, and it has been shown that they are specific, and recognizable as such, for the type of bacterium to which the body is reacting. From these investigations have come the diagnostic methods of blood counting, of agglutination reactions, of complement fixation tests and tests for tissue sensitivity to specific toxins, measures that often enable us to say with certainty what bacterium or toxin is responsible for the disease before us.

In summary, then, the physical diagnosis of disease is based to-day upon the naturalistic conception that all disease has a natural origin, runs a natural course, produces natural reactions in the body, results in natural changes in the body tissues and terminates by processes that are naturally understandable and detectable. The studies of anatomy, physiology, pathology, bacteriology and serology have yielded a vast fund of knowledge in support of this conception and have enabled us to recognize the effects of disease while they are in progress. The sciences of physics, chemistry and biology have widened the scope of diagnostic medicine and have led to scientific certainty in many of its investigations. Of course, with all this, much yet remains to be done, and much is being done day by day. Medicine now shares with science in general a pride in its accomplishments, a satisfaction in the knowledge that it has gained through painstaking investigation and honesty of effort and the humble realization that the future will modify some of its concepts, strengthen some and destroy others.

I have purposely left out of consideration the personal equation of the physician in diagnostic medicine. This would carry us into the intangible field of individual knowledge and judgment, and a discussion of it would lead nowhere. Suffice it to say that medicine has made for better doctors as medicine itself has grown into a better medicine. I have also failed to consider the mental and emotional fields of diagnostic medicine, not because they are lacking in importance, but because they do not lend themselves to the scientific approaches with which we have been dealing. It has been my purpose to show that physical diagnosis has in large part been mechanized, and to indicate the exact methods that clinical medicine has at its disposal today for determining the cause and nature of disease.

THE MAYA COUNTRY IN YUCATAN

By Dr. A. S. PEARSE
PROFESSOR OF ZOOLOGY, DUKE UNIVERSITY

THE Mayas have long occupied the Yucatan Peninsula and adjacent parts of Central America, particularly Guatemala and Honduras. The peninsula is for the most part a flat sheet of limestone which was raised out of the ocean in the Pleistocene epoch of geological history. It is so recent that it has not yet had time in most places to accumulate more than a very thin layer of soil. During the dry season when the sun shines on the surface of the ground, it gets very dry and hot. No point in the State of Yucatan is more than a thousand feet above sea level. The shrubs and trees are therefore semi-xerophytic in character. There are no rivers in Yucatan, but long brackish cienagas extend along the coast. Toward the base of the peninsula the forest grows heavier; rivers flow into the cienagas. Here grows the sapote tree, the secretions of which (*chicle*) furnish the basis for chewing gum; also Spanish cedar, mahogany and other valuable woods. Guatemala and Honduras are for the most part rather wet and when not disturbed by man are usually covered by swampy areas and heavy forests.

The Mayas have a glorious past. Before Columbus came to America they had built magnificent and ornate architectural works, all without the use of metal tools, wheels or keystone arches. They constructed fine roads, which were often paved and graded. In Yucatan there were two periods when Mayas built up great empires. The Old Empire thrived from about 350 A.D. to 670 A.D. Then there was a migration south for several hundred years, but from about 965 A.D. to 1450 A.D. the New Empire flourished and many of the great architectural monuments that stand to-day were built. All over Yucatan one encounters vegetation-covered mounds with bits of masonry showing here and there. The most accessible of the great ruins are at Chichen-Itza, where many buildings and monuments have been wholly or partially rebuilt by the Carnegie Institution and the Mexican Government, and at Uxmal.

The ancient Maya system of government was somewhat like that in medieval Europe. Great cities like Uxmal, Coba and Chichen-Itza were centers for trade, government and religion. The noblemen were priests, political administrators and warriors. Thousands of slaves captured during wars were used in constructing buildings and roads. Mercenary soldiers were brought in from other parts of Mexico. The culture of the Old Empire was largely Mayan, but during the golden age of the New Empire many Toltec institutions were introduced from the mainland of Mexico. Among these human sacrifice, ball courts and the feathered serpent may be mentioned.

When Montejo established Spanish colonies in Yucatan in the seventeenth century the glory of the New Empire had already departed. The Mayas in their best days supported a high order of culture. The architectural works are well known. The Mayas used two calendars, religious and fiscal, which were carefully integrated. Astronomers were able to predict eclipses accurately. Most of the stone monuments which the Mayas left in various places are covered with dates of important historical events; such as the inauguration of kings and

great battles. The written hieroglyphic codices of the Mayas were largely destroyed by bigoted Spanish priests while they were converting the Indians. Only three of these old manuscripts remain. In the later days of the empire jealousy and wars between the cities, and perhaps contributing causes, such as disease and famine, paved the way for the disintegration of high culture. When Montejo made his *entrada* the great buildings at Chichen-Itza and Uxmal were already overgrown with vegetation and falling into ruins.

The greatest hero in Mayan history is Kukulcan. He is said to have been brought to Chichen Itza as a captive and thrown at dawn into the Sacred Cenote as a sacrifice to the rain god. At noon he was alive. There had been a prophecy that if a man survived the cenote ordeal he was to be a great leader for the Mayan people. Kukulcan was accordingly taken out of the cenote and honored as a king. He proved to be a very wise and competent ruler. The Mayan Empire flourished under him. Later he was believed to be a god, in fact none other than Quetzalcoatl, who had condescended to appear in the form of a man to help the Mayas. Now he is a semi-mythological character.

At present, as in the past, the great problem for the Mayas in Yucatan is to get water. As there are no rivers, people depend on *cenotes,* great well-like perforations through the limestone which reach ground water; *aguadas,* shallow water holes which are often filled with aquatic vegetation; and *cuevas* (caves), where water drips slowly from the roof into pots or sometimes stands in little natural pools. As one travels through the country he finds that where there is a village there is usually a cenote.

The Mayas have from ancient times raised two crops on the thin rocky soil of Yucatan and they continue in much the same way to-day. Corn (*maise*) is raised by milpah farming. A tract of land is cleared of timber, which may be of value for building or fuel and then burned over. Corn is planted at the beginning of each rainy season (May) between the stumps and rocks for about two years, when the growth of other plants makes it difficult to continue to cultivate. A new milpah is then prepared. On account of limited water supply the ears of corn are usually rather small and the kernels hard, but the flavor is excellent. Another staple crop is hennequin, a fiber-producing plant, which requires seven to nine years to reach bearing size and then continues to produce fibrous leaves for about twenty years. Fruits are also often raised in the yards about houses—oranges, papayas, melons, soromoyas, mangoes, mames, aquacates, bananas, etc. Among the trees there are always chickens and pigs; also often goats and other domestic animals. Cattle are raised on haciendas everywhere. Toward the south in Quintana Roo and Campeche *chicleros* make a living by collecting chicle from the sapote tree, and there are many cattle.

It is pleasant to travel through the Maya country. Though one must often suffer minor inconveniences from mosquitoes, sand-flies, bedbugs, fleas, ticks, bad water and poor food, the little Indians are always honest, courteous and hospitable. A modern Maya wears a characteristic dress. He is generally very clean. The women are usually wide and dumpy. They wear a loose white gown, which has printed patterns or embroidery about the low neck and around the bottom. Often a fancy petticoat extends below the dress. Poor women are barefoot, but those who can afford to do so wear sandals (*alpargates*) or perhaps even high-heeled shoes. When going abroad, as to market or to

the mill where her *maise* is ground, a woman usually wears a bright-colored scarf over her head and about her shoulders. Often she carries a water pot on her hip or a dish of *maise* on her head. A man wears a white cotton shirt and pants, a large straw sombrero or no hat at all, sandals and a characteristic cotton apron which extends to his knees across the front, along one side and across the back but is open on the right side. Heavy burdens are carried on the back and supported by a strap across the forehead.

When one travels into the interior of Yucatan, he finds accommodations very simple. Even in hotels he expects nothing but food and two hooks on the wall. He hangs his own hammock, which he carries with him in a bag. Food always includes tortillas and frijoles; perhaps also chicken, pork, beef, squash, aguacates, tomatoes or other fruits. Mayas generally drink *pozole*, which consists of raw corn meal in cold water. This beverage becomes quite sour after a few hours. Affluent persons imbibe chocolate at the end of a meal. The chocolate

A YOUNG MAYAN WOMAN.

MAKING ROPE FROM SISAL.

EL CASTILLO, CHICHEN ITZA; SAID TO HAVE BEEN BUILT BY KUKULCAN.

is flavored with cinnamon in the usual Mexican style and makes a very agreeable drink. The foods of the Mayas are not prepared or served in a very sanitary way. Intestinal diseases are therefore prevalent, especially amoebic dysentery.

Mayas are Roman Catholics. Little shrines often occur along roadways, and almost every thatched hut contains a

THE INITIAL SERIES LINTEL, 619 A.D.; CHICHEN ITZA.

simple one. Pictures of virgins and crosses are supported by candles and flowers in old liquor bottles. Large haciendas often provide churches for the Indian laborers. In the large towns there are cathedrals, many now wholly or partly in ruins with the recent decline of the church in Mexico. In some localities church buildings are now used for schools, restaurants and other purposes.

Where land has not been cleared for milpahs or hennequin haciendas it remains in a rather primitive state, covered by low trees and shrubs. There are a few roads suitable for automobiles, but most of the country roads are difficult even on horseback or in a cart. During the rainy season they consist of alternating strips of shallow canals and rough rocky ridges. Most Mayas make their journeys on foot with their burdens on their backs. Parts of Quintana Roo have never been conquered or surveyed by Spaniards or Mexicans.

As one goes along the country roads afoot or on a horse thorny shrubs reach out and snatch his hat off or tear holes in his shirt. Along the way giant cacti are interspersed with acacias, agaves and other semi-xerophytic plants. Leaf-

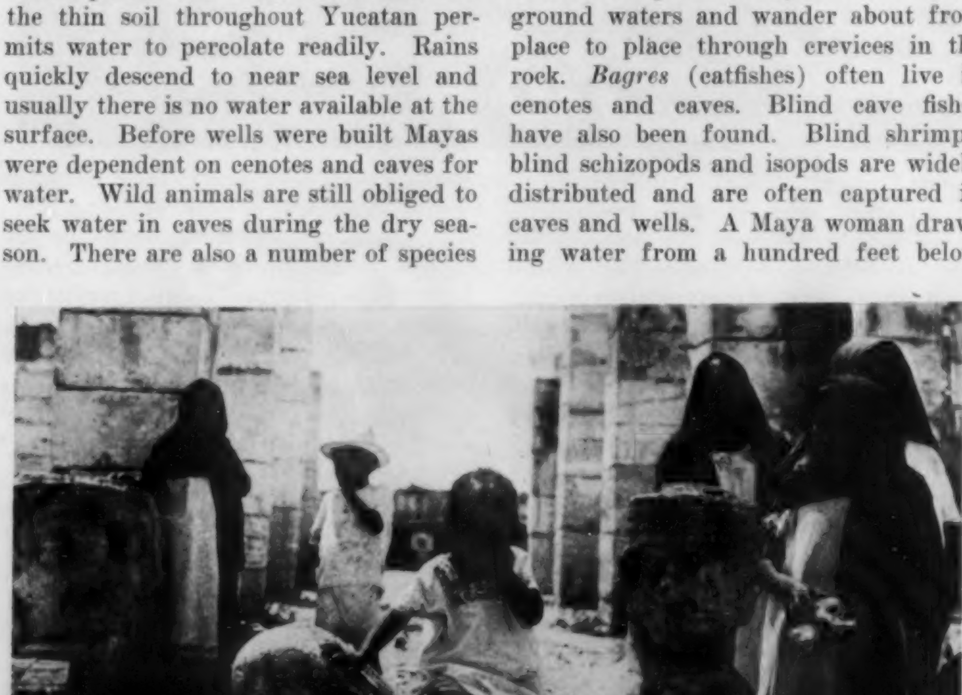
CATHEDRAL AT OXKUTZCAB.

cutter ants march in long armies bearing bits of leaves to the fungus beds within their great nest mounds. Doves and quail are common. Morning and evening cardinals and other beautiful song birds make the trails pleasant, but at midday little life is to be seen. One often meets an Indian with a deer. Occasionally a peccary, porcupine, agouti or fox may be seen. *Sapolotes* (buzzards) are everywhere. In the rocky crevices of cenotes twittering swallows and motmots build their nests. The latter are beautiful, hoarse-voiced, iridescent birds with long tails which they continually wag from side to side.

SOCIALIST GOVERNMENT SCHOOL; KAUA.

MAYA FIGURINES.

The porous limestone which underlies the thin soil throughout Yucatan permits water to percolate readily. Rains quickly descend to near sea level and usually there is no water available at the surface. Before wells were built Mayas were dependent on cenotes and caves for water. Wild animals are still obliged to seek water in caves during the dry season. There are also a number of species which live permanently in the underground waters and wander about from place to place through crevices in the rock. *Bagres* (catfishes) often live in cenotes and caves. Blind cave fishes have also been found. Blind shrimps, blind schizopods and isopods are widely distributed and are often captured in caves and wells. A Maya woman drawing water from a hundred feet below



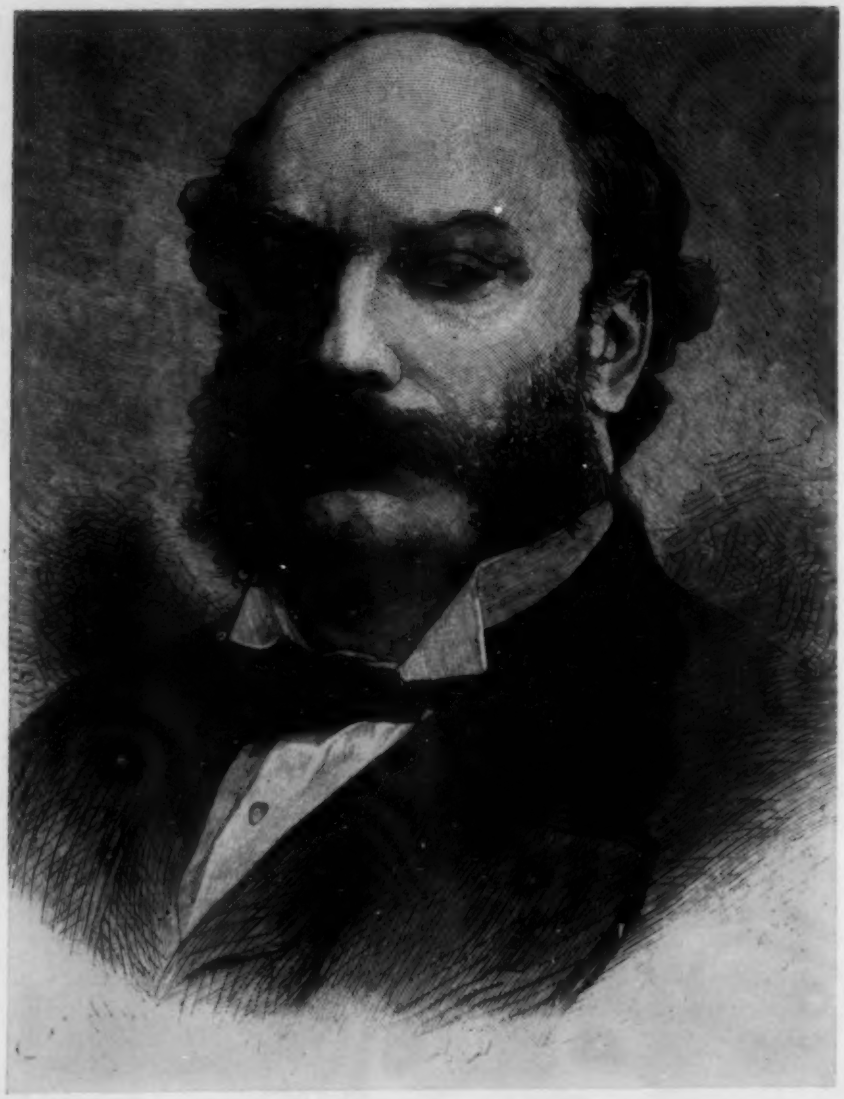
MAYA GIRL SEATED ON A CHAC MOL; TEMPLE OF WARRIORS, CHICHEN ITZA.

may find a white, blind crustacean swimming about in her bucket.

At present social and political conditions are changing in Yucatan. The old order wherein wealthy *haciendados* dominated great plantations and were the local rulers of hordes of illiterate peons is giving way to a new socialistic government. State schools are being established everywhere, and parochial schools have lost their influence or have been closed altogether. There are two types of teachers; some hired by the federal government and some by local authorities. In certain districts the teachings of the former were so unpopular that the teachers were killed by the natives. Labor unions dominate certain activities and are often not well organized. The baggage handlers union pesters the traveler with petty fees for unnecessary services at docks and railway stations. Most of the *haciendas* are deserted by the owners because their laborers no longer look upon them as benign patrons, but demand impossible privileges or wages and even attack their employers. Village police usually suspect that any stranger is looking for gold, and *presidentes* demand that a stranger appear before them to explain his business. In addition to bull-fighting and baseball, one of the open sports is shooting governors and other officials.

JAGUAR AND EAGLE HOLDING HUMAN HEARTS; CHICHEN ITZA.

Men of property are discouraged because the federal government is confiscating their lands and apportioning them among Indians. During the year 1936 little or no hennequin was planted in Yucatan by the *haciendados*. They felt that it would be wasted effort because their lands would soon be confiscated and given to poor men who will have neither knowledge or means to manufacture hemp or market it. So times are bad in Yucatan; but the country and the people are good.



THE LATE LORD RAYLEIGH

President of the British Association for the Advancement of Science in 1884. Reproduced from the Popular Science Monthly (now The Scientific Monthly), October, 1884.

THE PROGRESS OF SCIENCE

FATHER AND SON AS PRESIDENTS OF THE BRITISH ASSOCIATION

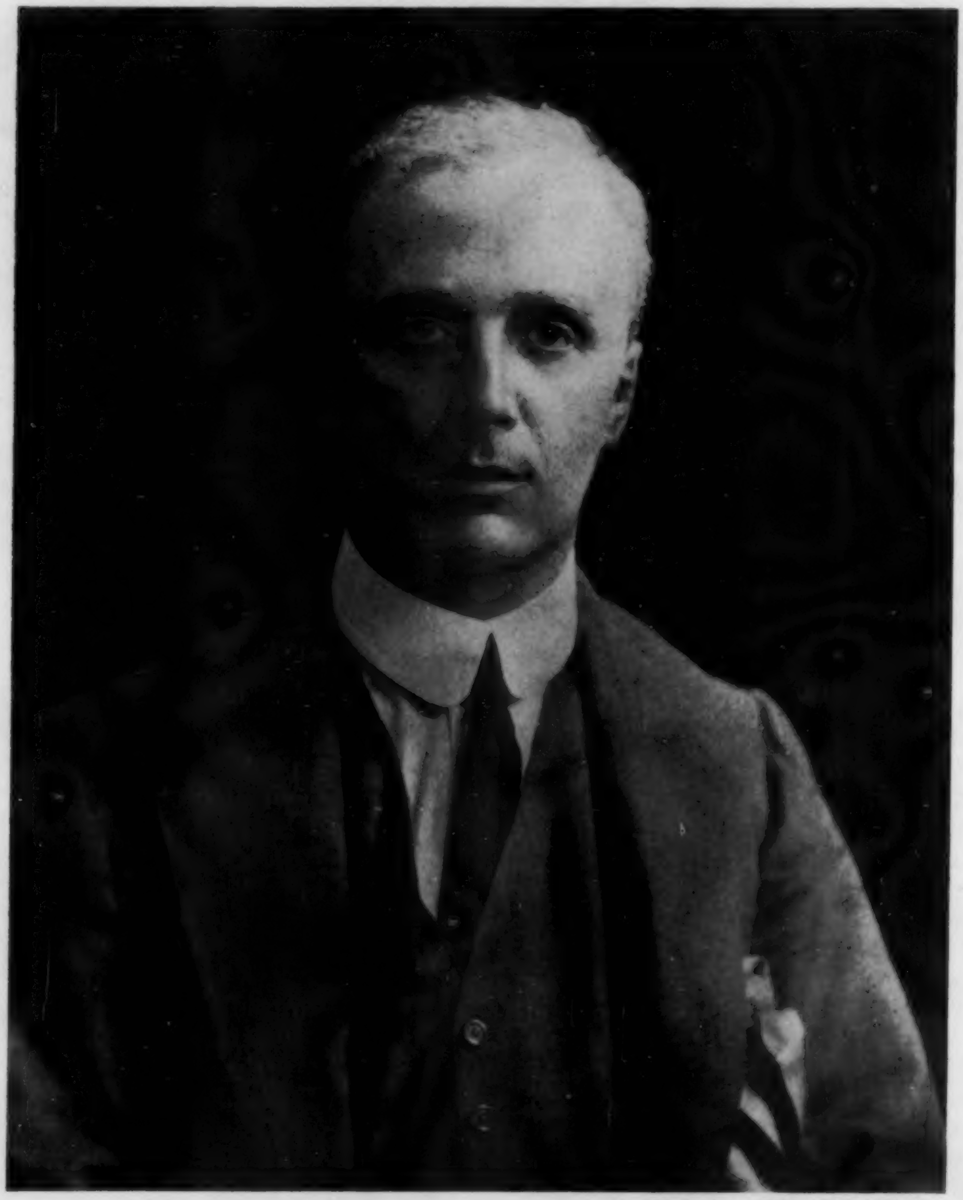
Lord Rayleigh has been elected president of the British Association for the Advancement of Science to succeed Sir Edward Poulton. Lord Rayleigh's father was also president of the association; his presidential address, given in Montreal in 1884, is reprinted as the leading article in this issue of The Scientific Monthly. The address was originally in the Popular Science now The Scientific Monthly for October, 1884.

The address, covering as it does the development of physics at that time, is particularly interesting in view of the continuous progress of physics, for it was Lord Rayleigh, Sir William Thomson (later Lord Kelvin), James Clerk Maxwell, Sir J. J. Thomson, Willard Gibbs, Hertz, von Helmholtz and their contemporaries who laid the foundations of the modern science of physics.

In introducing Lord Rayleigh at the first assemblage of the association at Montreal, Sir William Thomson said: "Professor Cayley [who preceded Lord Rayleigh in the presidency] has devoted his life to the advancement of pure mathematics. It is indeed peculiarly appropriate that he should be followed in the honorable post of president by one who has done so much to apply mathematical power in the various branches of physical science as Lord Rayleigh has done. In the field of discovery and demonstration of natural phenomena Lord Rayleigh has, above all others, enriched physical science by the application of mathematical analysis. . . . In reading some of the pages of the greatest investigators of mathematics one is apt occasionally to become wearied, and I must confess that some of the pages of Lord Rayleigh's work have taxed me most severely, but the strain was well repaid. When we pass from the instrument which is harsh and crabbed to those who do not give themselves the trouble to learn it thoroughly, to the application of the instrument, see what a splendid world of light, beauty and music is opened to us through such investigations as those of Lord Rayleigh! His book on sound is the greatest piece of mathematical investigation we know of applied to a branch of physical science."

This feature of his work, its extreme accuracy and definiteness, the combination of mathematical acumen with experimental skill is the measure of its greatness. A large part of his work consisted in the examination of things concerning which the superficial facts were already known. In this way he furnished a great mass of detailed and precise material. In fact, he covered the greater portion of the entire field of physics filling in many gaps by experiment, calculation and thought. The subjects to which he contributed include chemical physics, capillarity and viscosity, the theory of gases, the flow of liquids, photography, optics, color vision, the wave theory, electricity and magnetism, electrical measurements, elasticity, hydrodynamics and sound, the last named being the subject of his most extensive work, "The Theory of Sound," a mathematical treatise published in 1877–1878. While this is his most important work the discovery of argon in 1904 is the most widely known. The numerous memoirs in which his original work appeared were later published together under his editorship. The last of these volumes appeared in 1903.

Lord Rayleigh's earlier papers were written under the name of J. W. Strutt, for he succeeded to the title in 1872, after he had become well known as a physicist.



—*Photo from Wide World Photos*

LORD RAYLEIGH

PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

He was born on November 12, 1842. He did not attend a public school because of poor health; however, he attended Trinity College, Cambridge, and was graduated in 1865 with distinguished honors. Following the usual custom, when a student of a college has distinguished himself in the final examination, Trinity College elected him to a fellowship, which he relinquished on his marriage in 1871. He succeeded Clerk Maxwell as Cavendish professor of experimental physics at the University of Cambridge, occupying this chair from 1879 to 1884. In 1887 he became professor of natural philosophy at the Royal Institution of Great Britain, from which he resigned in 1905. He devoted much time to the organization of the Cavendish Laboratory, the gift of the eighth Duke of Devonshire, chancellor of the University of Cambridge, whom Lord Rayleigh succeeded in the chancellorship in 1908. He was elected a fellow of the Royal Society in 1873, and was president of the society from 1905 to 1908. He was one of the original members of the Order of Merit, instituted in connection with the coronation of King Edward VII. He received the Nobel Prize in 1904.

The present Lord Rayleigh was born on August 28, 1875, and attended Eton and Trinity College, Cambridge. He is now emeritus professor of physics at the Imperial College of Science, South Kensington. He was Bakerian lecturer in 1911 and 1919 and has been at various times foreign secretary of the Royal Society, president of the Section of Mathematics and Physics of the British Association for the Advancement of Science and president of the Physical Society. He is chairman of the governors of the Imperial College of Science and Technology and of the executive committee of the National Physical Laboratory.

Lord Rayleigh's influence on the development of physical science has been profound. As is stated in *Nature:* "First and foremost an experimental physicist, he has his father's flair for recognizing those aspects of an experimental investigation which most need stressing and for extracting results of fundamental importance from apparatus of simple, even primitive type. His work on radium and the earth's heat is classic in quality, and he has elucidated many diverse, and yet related, phenomena in his studies of the aurora borealis, the light of the night sky, the green flash and the fluorescence of mercury vapor. He has lately studied the conditions of optical contact of glass surfaces, and has investigated, by admirably simple methods, the pull required to separate, and the work done in separating, contacted surfaces. He has measured the small amount of reflection between two contacted glass surfaces and has shown that the blackness of the black center of the Newton's rings formed between a spherical and a plane surface is by no means perfect."

J. G.

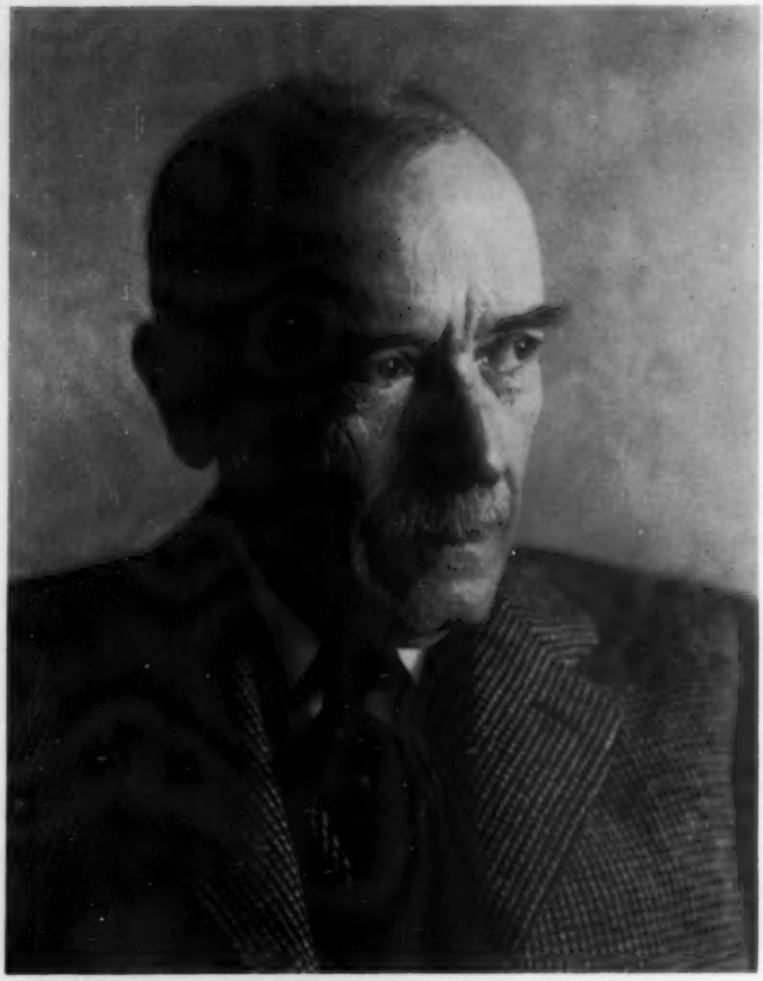
UNIVERSITY PRESIDENTS WHO HAVE BEEN PSYCHOLOGISTS

In the old days the college president was nearly always a clergyman, usually one who was or had been a professor. The president of Lafayette College, in whom the writer of this note is interested above all others, was typical—a professor of the classics, then for three years a Presbyterian pastor, then in 1863 called to the presidency of the college, being also professor of philosophy. Eliot was the first lay president at Harvard, Hadley at Yale, Wilson at Princeton. With the founding and growth of the state universities and the development of the colleges from the status of theological preparatory schools, with the advance of science, technology, medicine and law, many colleges became universities and a new type of president was sought. Those mentioned above are typical, as are Gilman at the Johns Hopkins, White at Cornell and Angell at Michigan. These

DR. WILLIAM LOWE BRYAN
PRESIDENT OF INDIANA UNIVERSITY FROM 1902 TO 1937. DR. BRYAN GRADUATED FROM INDIANA UNIVERSITY IN 1884; STUDIED IN BERLIN, WÜRZBURG AND PARIS AND RECEIVED THE DOCTOR OF PHILOSOPHY DEGREE AT CLARK UNIVERSITY IN 1892 UNDER STANLEY HALL. HE THEN BECAME PROFESSOR OF PHILOSOPHY AND PSYCHOLOGY AT INDIANA UNIVERSITY. HE WAS PRESIDENT OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION IN 1903. HIS EARLY WORK ON THE MEASUREMENT OF MOTOR ABILITY AND THE PRACTICE CURVE HAS BEEN OF FUNDAMENTAL IMPORTANCE IN EXPERIMENTAL PSYCHOLOGY.

presidents were scholars, but the increasing complexity of the universities seemed to require men who were primarily executives; some rich business men were selected, as Low, a tea merchant, at Columbia; Harrison, a sugar merchant, at Pennsylvania.

At that time there emerged a new science—psychology—the rapid progress of which in America being in part due to the fact that the president was no longer a clergyman who taught mental philosophy. The first chair of psychology, here or abroad, was established for Cattell at the University of Pennsylvania in 1888; he moved to Columbia in 1891. Then in rapid succession chairs of psychology were established in nearly all our lead-

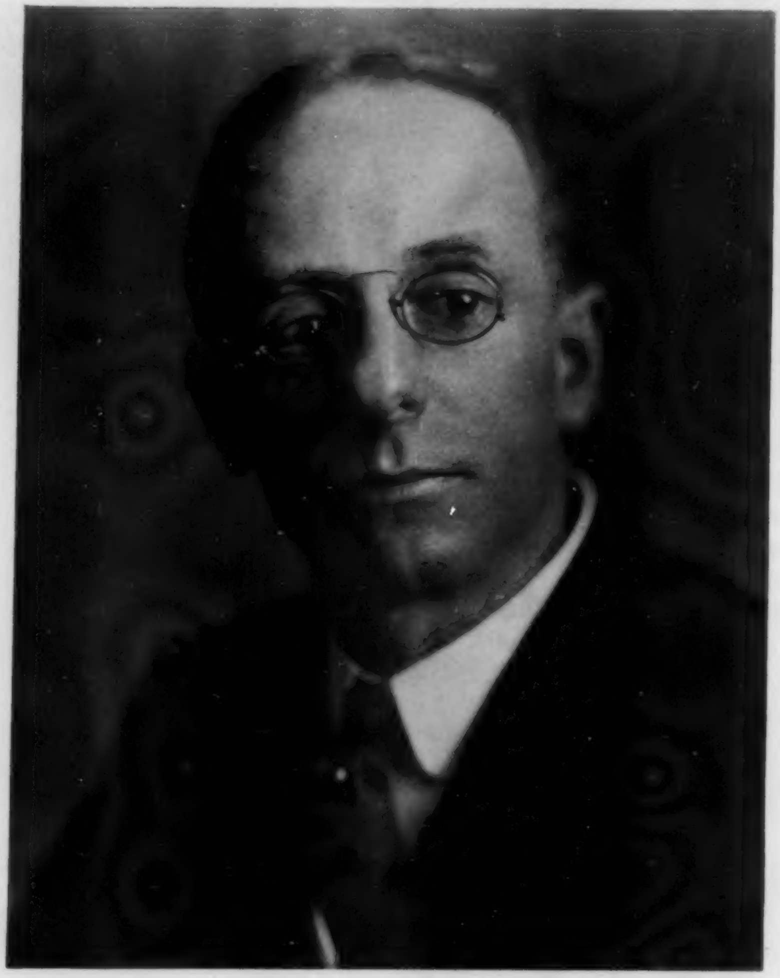


DR. LIVINGSTON FARRAND

PRESIDENT OF CORNELL UNIVERSITY FROM 1921 TO 1937. DR. FARRAND GRADUATED FROM PRINCETON UNIVERSITY IN 1888 AND THE COLUMBIA MEDICAL SCHOOL IN 1891, HAVING BEEN AT THE SAME TIME A STUDENT OF PSYCHOLOGY IN THE UNIVERSITY, WHICH STUDY HE CONTINUED AT THE UNIVERSITY OF CAMBRIDGE. HE BECAME INSTRUCTOR IN PSYCHOLOGY IN COLUMBIA UNIVERSITY IN 1903 AND LATER PROFESSOR OF PSYCHOLOGY AND OF ANTHROPOLOGY. HE WAS PRESIDENT OF THE UNIVERSITY OF COLORADO FROM 1914 TO 1919 AND THEN CHAIRMAN OF THE EXECUTIVE COMMITTEE OF THE RED CROSS. HE WAS SECRETARY OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION FROM 1895 TO 1904. A PAPER BY CATTELL AND FARRAND, ENTITLED "PHYSICAL AND MENTAL MEASUREMENTS OF THE STUDENTS OF COLUMBIA UNIVERSITY," PUBLISHED IN 1896, IS GENERALLY REGARDED AS HAVING LAID THE FOUNDATION FOR WORK ON INDIVIDUAL DIFFERENCES AND THE USE OF PSYCHOLOGICAL MEASUREMENTS IN SCHOOLS AND COLLEGES.

ing universities. In 1889 William James was transferred from an associate professorship of philosophy to a chair of psychology at Harvard and published the following year his great work on psychology. Münsterberg was called from Germany to Harvard and Titchener from England to Cornell in 1892. Within this short period from 1888 to 1892 chairs of psychology were established at Wisconsin, Indiana, Nebraska, Brown, Wellesley, Stanford, Clark, Illinois, Toronto, Princeton and elsewhere.

Contemporaneously with this remark-



DR. JAMES ROWLAND ANGELL

DR. ANGELL GRADUATED IN 1890 FROM THE UNIVERSITY OF MICHIGAN, WHERE HIS DISTINGUISHED FATHER, JAMES BURRILL ANGELL, WAS PRESIDENT. HE RECEIVED THE MASTER'S DEGREE FROM HARVARD UNIVERSITY AND WAS PROFESSOR OF PSYCHOLOGY AND DIRECTOR OF THE PSYCHOLOGICAL LABORATORY AT THE UNIVERSITY OF CHICAGO FROM 1901 TO 1920, HAVING BEEN ALSO DEAN AND AT ONE TIME ACTING PRESIDENT. HE WAS CHAIRMAN OF THE NATIONAL RESEARCH COUNCIL IN 1919 AND PRESIDENT OF THE CARNEGIE CORPORATION IN 1920. HE WAS PRESIDENT OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION IN 1906 AND VICE-PRESIDENT OF THE INTERNATIONAL CONGRESS OF PSYCHOLOGY MEETING AT YALE UNIVERSITY IN 1929.

able advance of psychology there was a corresponding development of the teaching of education—pedagogy it was then called—in our universities. It began in the state universities, but received its most notable advance in the appointment of Professor Hanus at Harvard in 1891 by President Eliot against the opposition of the faculty. Dr. Butler in 1890 became professor of philosophy and education at Columbia; he had established *The Educational Review* in 1889. Dr. Russell became dean of the newly established Teachers College at Columbia in 1897.

Psychology and education, which should be an applied science based primarily on psychology, seemed the most logical fields from which to draw the

president of a university, if he were to be an educational leader rather than an orator and collector of money. Stanley Hall became president of the newly established Clark University in 1888, Dr. Butler president of Columbia in 1902. There have since been other professional students of education who became university presidents, as Dr. Coffman at Minnesota, Dr. Elliott at Purdue and Dr. Capen at Buffalo. A number of psychologists were elected to be presidents at that time or later, three of whom have just now retired; President Bryan at Indiana, President Farrand at Cornell and President Angell at Yale. Others are President Scott at Northwestern, President Lindley at Kansas and President Chase at New York University.

University presidents are now drawn from nearly all sources. The principal of McGill University, Mr. Douglas, elected last month, is a business man and publicist, but there appears to be a tendency to select professors from the departments of political science, economics and history, as Dr. Seymour at Yale, Dr. Day at Cornell, Dr. Dodd at Princeton. Dr. Conant at Harvard, however, is a chemist. The change in the attitude and function of the American university since the Johns Hopkins University was opened in 1876 is indicated by the fact that Dr. Conant is a research chemist of distinction, whereas Eliot was a teacher of chemistry.

J. McK. C.

SCIENCE IN PALESTINE

WITH Palestine a natural laboratory, great scientific strides have been made by the Hebrew University in Palestine since its inception ten years ago—strides that have had a marked effect on the industrial, social and commercial development of the country. In this comparatively short time there are already visible benefits in Palestine resulting from the work done at the university in hygiene, bacteriology, zoology, physics, chemistry, biology, botany, geology and archeology.

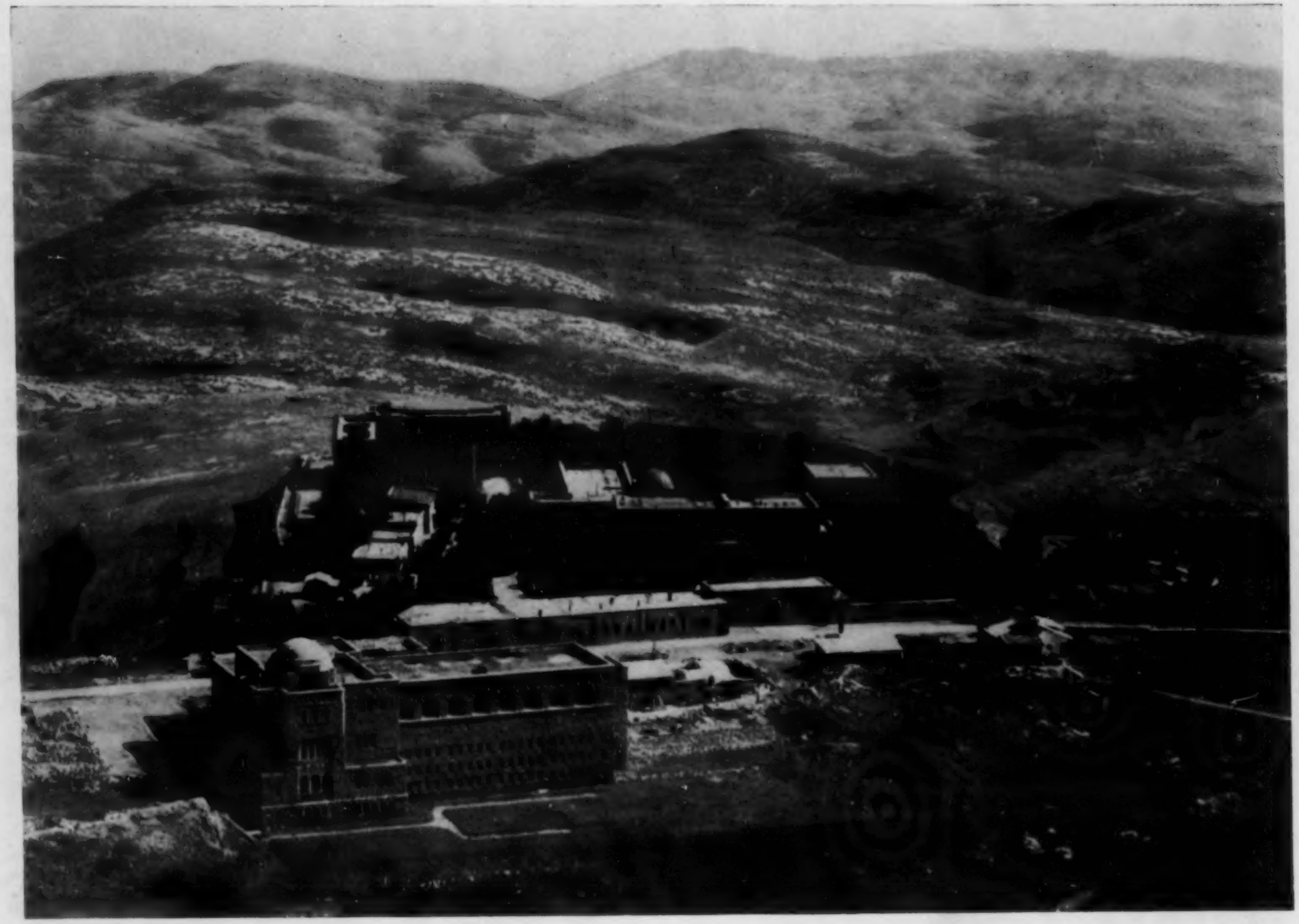
Researches conducted by the Institute of Chemistry in the field of soil formation and soil chemistry have supplied invaluable data on Palestinian phosphates, minerals, fermentation of tobacco and the utilization of alcohol, which have not only solved problems for industries already established there, but have opened up new fields for commercial enterprise.

For the biologist, Palestine offers a singularly valuable field of research. Here the flora and fauna of the Mediterranean region meet with those of the great desert belt that stretches from Morocco to Turkestan. In the Jordan Valley, tropical influences are to be found, while only a few hundred kilometers away are the snow-covered slopes of Mount Hermon in the Lebanon. With such sudden transitions, the influence of extreme factors on the distribution of living organisms can be investigated much better than at any other place.

The recently inaugurated Botanical Garden at the university is a reproduction of the ancient wood growths of the Palestinian hillsides in their virgin and pristine form. Much of the research work of the department of botany is also being concentrated in the study of plant physiology on the water metabolism of the plants.

The university contains the only Museum of Biblical Botany in existence, including the floral prototype of the Menorah (seven-branched candelabrum) and the Rose of Sharon, as well as many other plants mentioned in the Scriptures. Successful projects in afforestation, irrigation and the cultivation of new products are also to be credited to the department of botany.

The work of the department of hygiene and bacteriology, aided by the Malaria



AN AERIAL VIEW OF THE HEBREW UNIVERSITY IN PALESTINE WITH THE DAVID WOLFFSOHN MEMORIAL LIBRARY IN THE FOREGROUND.

CORRIDOR IN EINSTEIN INSTITUTE OF PHYSICS AND MATHEMATICS
HEBREW UNIVERSITY IN JERUSALEM, PALESTINE, SHOWING BUST OF MAIMONIDES, MEDIEVAL JEWISH PHILOSOPHER.

Research Station, partially subsidized by the League of Nations Health Commission, and the cancer and radium institutes, the first of their kind in the Near East, has had considerable effect in improving the health conditions in that region.

Observations made by the Malaria Research Station, which resulted in successfully combatting the disease in the Near East, showed that the anopheline mosquitoes behaved differently during the prehibernating season from the active breeding period in the spring and early summer. During the former time the insects disperse over large areas, from twelve to fourteen kilometers from their breeding place. It was also discovered that, contrary to accepted belief, anopheline mosquitoes feed in the open on people or animals sleeping out-of-doors near their habitats. Children below the age of four to six were discovered to develop no immunity to malaria infection even after repeated attacks, reinfection occurring frequently immediately after a cure.

Considerable progress has been made by the department of bacteriology in ascertaining the relation of climate to susceptibility to disease. High temperature, associated with a high relative humidity, plus excessive exposure to solar radiation, increases host susceptibility to typhoid infection. It was also found that at high temperature there is a higher Vitamin B requirement, and that with an insufficient Vitamin B intake, the high-fat-containing diets, common in temperate countries, are distinctly harmful in tropical and subtropical climates. These observations have led to the successful treatment, with proper nutrition, of infantile toxicosis prevalent among certain classes of children during the hot season.

The department of parasitology, under the direction of Dr. Saul Adler, whose

AN AERIAL VIEW OF THE HEBREW UNIVERSITY IN PALESTINE WITH THE DAVID WOLFFSOHN MEMORIAL LIBRARY IN THE FOREGROUND.

A LABORATORY CLASS IN BOTANY AT THE HEBREW UNIVERSITY IN PALESTINE.

researches won him the Chalmers Medal, the highest award of the Royal Society of England, has made considerable progress in alleviating cattle diseases by its researches in kala-azar, or sand-fly fever, and theileriosis, or East Coast cattle fever. Great benefits have been derived agriculturally in Palestine by the researches of the department of zoology in migratory locusts, as well as in methods of combatting some of the citrus insects.

Exploration of uninhabited regions in the southern and eastern parts of Palestine has been made by the geology department at the university with the purpose of discovering new territories for settlement. Construction activities in Palestine have also been considerably aided by the work of the Materials Testing Laboratory in ascertaining the type of construction material suitable for the climate.

With Palestine and neighboring regions a rich source for archeologists, tremendous progress has been made in archeological discoveries conducted by the university in cooperation with Harvard University and similar institutions. Ancient Jewish tombs and synagogues found by the university's archeologists have done much to fill in wide historical gaps, while the recent discoveries of the Lachish potsherds, traced back to the time of Jeremiah, have done much to confirm the historical accuracy of the Bible.

According to plans of the university for the next few years, an expansion of scientific activities is expected. The plans include the founding of a School of Sub-Tropical Medicine, with the erection of the Hadassah-University Hospital and the Medical Building, already under way. Other projects of great scientific significance are the establishment of a meteorological station, an engineering school, an agricultural college, an institute of natural and exact sciences and a museum of natural history.

A. F.